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DOD 6055.9-STD

DEPARTMENT OF DEFENSE

DOD AMMUNITION AND EXPLOSIVES SAFETY STANDARDS

AUGUST 1997

Under Secretary of Defense
for Acquisition and Technology

ACQUISITION AND
TECHNOLOGY

THE OFFICE OFTHE UNDER SECRETARY OF DEFENSE

3000 DEFENSE PENTAGON
WASHINGTON, D.C. 20301-3000

AUG 11 1997

FOREWORD

This Standard is issued under the authority of DoD Directive 6055.9, "DoD Explosives Safety Board (DDESB) and DoD Component Explosives Safety Responsibilities," July 29, 1996. It establishes uniform safety standards applicable to ammunition and explosives, to associated personnel and property, and to unrelated personnel and property exposed to the potential damaging effects of an accident involving ammunition and explosives during their development, manufacturing, testing, transportation, handling, storage, maintenance, demilitarization, and disposal.

DoD 6055.9-STD, "Ammunition and Explosives Safety Standards," October 1992 is hereby canceled. This Standard applies to the Office of the Secretary of Defense, the Military Departments, the Chairman of the Joint Chiefs of Staff, the Combatant Commands, and the Defense Agencies (hereafter referred to collectively as "the DoD Components").

This Standard is effective immediately and is mandatory for use by all DoD Components. The heads of DoD Components may issue supplementary instructions only when necessary to provide unique requirements within their respective Components. A copy of supplementary instructions shall be forwarded to the Chairman, DDESB.

Forward recommendations for change to this Standard through channels to:

Chairman
Department of Defense Explosives Safety Board
2461 Eisenhower Avenue
Alexandria, VA 22331-0600

The DoD Components may obtain copies of this Standard through their own publications channels. It is approved for public release, distribution unlimited. Authorized registered users may obtain copies of this publication from the Defense Technical Information Center, 8725 John J. Kingman Rd., Suite 0944, Ft Belvoir, VA 22060-6218. Other Federal Agencies and the public may obtain copies from the U.S. Department of Commerce, National Technical Information Service, 5285 Port Royal Road, Springfield, VA 27161. Report Control Symbols DD-A&T(AR)1643 and DD-A&T(AR)1020 have been assigned to the reports required by this Standard.

R. Noel Longuemare
Acting Under Secretary of Defense
(Acquisition and Technology)

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(b) Department of Defense Explosives Safety Board (DDESB) Technical Paper No. 13, "Prediction of Building Debris for Quantity-Distance Siting," April 1991

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(d) ST/SG/AC.10/1/Rev. 10, "Recommendations of the Transport of Dangerous Goods," Ninth Revised Edition, United Nations, New York, 1995

(e) TB 700-2, Naval Sea Systems Command Instruction (NAVSEAINST) 8020.8A, TO 11A-1-47, Defense Logistics Service Acquisition Regulations (DLAR) 8220.1, "Explosives Hazard Classification Procedures," December 1989

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(y) ARLCD-CR-80049, "Engineering Guide for Fire Protection and Detection Systems of Army Ammunition Plants - Volume I, Section and Design," December 1980

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(aa) DoD Instruction 6055.7, "Mishap Investigation, Reporting, and Recordkeeping," April 10, 1989

ABBREVIATIONS AND ACRONYMS

AEL	airborne exposure limits
BLAHA	basic load ammunition holding area
CB	chemical/biological
CBU	cluster bomb unit
CE	civil engineer
CG	compatibility group
COE	Corps of Engineers
CONUS	continental United States
DDESB	Department of Defense Explosives Safety Board
DODAC	Department of Defense ammunition code
DOT	Department of Transportation
DPE	demilitarization protective ensemble
DTA	differential thermal analysis
ECM	earth-covered magazine
EED	electroexplosive device
EIDS	extremely insensitive detonating substances
EMR	electromagnetic radiation
EOD	explosive ordnance disposal
ES	exposed site
FAE	fuel-air explosives
FSC	Federal supply class
FUDS	formerly used defense sites
GSA	General Services Administration
HAS	hardened aircraft shelter
HC	hexachlorethane
HE	high explosive
IAW	in accordance with
IBD	inhabited building distance
ILD	intraline distance
IMD	intermagazine distance
IMO	International Maritime Organization
IPS	inches per second
ISO	International Standardization Organization
LOX	liquid oxygen
MCE	maximum credible event
MILVANS	military vans
Mk	Mark
Mod	Model
MPS	maritime pre-positioning ships
MSHA	Mine Safety and Health Administration
MWD	military working dogs
MWR	morale, welfare, and recreation

NALC	navy ammunition logistic code
NATO	North Atlantic Treaty Organization
NEQ	net explosive quantity
NEW	net explosive weight
NIN	National identification number
NIOSH	National Institute Occupational Safety and Health
NSN	National stock number
PES	potential explosion site
PETN	pentaerythritol tetranitrate
POL	petroleum, oils, lubricants
POTMC	protective outfit toxicological microclimate controlled
PPE	personnel protection equipment
PSI	pounds per square inch
PTR	public traffic route
PWP	plasticized white phosphorus
Q-D	quantity-distance
R&R	rest & recreation
RDT&E	research, development, test and evaluation
RDX	cyclonite
SCBA	self-contained breathing apparatus
TAPES	toxicologic agent protective ensemble, self-contained
TEA	triethyl aluminum
TNT	trinitrotoluene
TWA	time weighted average
UNO	United Nations Organization
UXO	unexploded ordnance
WP	white phosphorus

CHAPTER 1

INTRODUCTION

A. Policy

It is DoD policy consistent with operational requirements to:

1. Provide the maximum possible protection to personnel and property, both inside and outside the installation, from the damaging effects of potential accidents involving DoD ammunition and explosives.

2. Limit the exposure of a minimum number of persons, for a minimum time, to the minimum amount of ammunition and explosives consistent with safe and efficient operations.

3. Comply with these ammunition and explosives safety standards. When DoD ammunition and explosives are located in overseas areas, comply with U.S. ammunition and explosives safety standards except when compliance with more restrictive local standards is made mandatory by an appropriate international agreement. When such ammunition is not in U.S. custody and under U.S. control, comply with U.S. standards to the extent consistent with agreements or arrangements with the host country concerned.

B. Scope

1. Ammunition and explosives safety standards herein shall be considered minimum and greater protection shall be afforded when practicable. They apply whenever any explosives, propellants, or similar energetic materials are present on DoD-owned or -leased facilities and to U. S.-titled ammunition in host nation facilities.

2. Standards herein shall govern DoD facilities siting and construction except:

a. When facilities already have been constructed or approved for construction to meet plans that were developed before the date of this Publication.

b. Existing facilities that do not comply with these standards (when current hazards are not greater than those assumed for their original use) shall be allowed for the balance of their useful lives when it can be demonstrated clearly that redesign or modification is not feasible, and that the quantity of explosives, propellants, or chemical agents cannot be reduced for reasons of operational necessity.

c. Planned facilities that do not meet these standards, but have been certified by the head of the DoD Component as essential because of operational necessity or other compelling reasons.

d. Other situations that upon analysis by the DoD Component and the DoD Explosives Safety Board (DDESB) are determined to provide the required degree of safety through use of protective construction or other specialized safety features.

3. The excepted deviations from these standards in subsection B.2., above, must be documented in the permanent records of the installation. This document must show the date the

applicable standard was first published and the date the deviant facility was approved for safety or was first used in the deviating manner.

C. DoD ammunition and explosives safety standards waiver and exemption program

1. **General**. The ammunition and explosives safety standards herein are designed to provide protection against serious injury, loss of life, and damage to property but are not intended to be so rigid as to prevent the DoD Components from accomplishing their assigned missions. Consequently, when deviating from these standards, proper authority within the DoD Components must weigh the added risk to personnel and property against the strategic and other compelling reasons that necessitate such deviations.

a. A waiver is written authority that permits temporary deviation from a mandatory requirement of these standards for strategic or other compelling reasons. Generally, it is granted for a short period pending cancellation or correction of the waived conditions. Waivers will not be granted for periods exceeding 5 years. Exceptional situations may require time for completion of corrective action or actions that exceed 5 years, in which case the waiver shall be reissued by the next higher approval authority unless the waiver was last issued at the Military Service head level. Waivers may be granted by the official with (1) assigned responsibilities consistent with the level of risk and (2) the authority to control the resources required to accomplish corrective action. Waivers will be reviewed for applicability and currency at intervals not exceeding 2 years.

b. An exemption is written authority that permits long term noncompliance with these standards for strategic or other compelling reasons. Exemptions may be granted by law, by congressional action, or by appropriate military authority. Appropriate military authority shall be that official with assigned responsibilities consistent with the level of risk. Exemptions shall be reviewed for applicability and currency at intervals not to exceed 5 years.

2. **Information requirements**. Upon request, DoD Components shall provide the DDESB with the following information (as applicable) on exemptions and waivers granted to the standards contained herein and any changes thereto. This reporting requirement has been assigned Report Control Symbol DD-A&T(AR)1643 in accordance with DoD 8910.1-M (reference (a)).

a. Identification number (DoD Component-derived) and classification (waiver or exemption in accordance with classification procedure cited in paragraphs C.1.a. and C.1.b., above).

b. Location and condition waived or exempted.

(1) Total explosive weight by hazard classification/division at a potential explosion site (PES).

(2) Distance to exposed site or sites (ES) from PES and brief description of ES to include type and estimated value of property and whether property is located on or off installation.

(3) Estimated number of personnel on and off the installation located at the ES.

(4) Calculated public access exclusion distance.

c. Date of approval, expiration, or cancellation as appropriate and title of approving authority.

d. Planned corrective action with date of expected completion.

(1) Estimated cost to correct.

(2) Military construction project number, if assigned.

CHAPTER 2

EFFECTS OF EXPLOSIONS AND PERMISSIBLE EXPOSURES

A. Introduction

In the assessment of the hazard associated with a given situation, the principal effects of the explosive output to be considered are blast pressure, primary and secondary fragments, thermal hazards, and chemical agent hazards. In this Chapter the effects of these hazards and permissible exposures are detailed.

B. Blast pressure output

1. **Blast wave phenomena**. The violent release of energy from a detonation in a gaseous medium gives a sudden pressure increase in that medium. The pressure disturbance, termed the blast wave, is characterized by an almost instantaneous rise from the ambient pressure to a peak incident pressure (Pso). This pressure increase, or shock front, travels radially from the burst point with a diminishing velocity that always is in excess of the sonic velocity of the medium. Gas molecules making up the front move at lower velocities. This latter particle velocity is associated with a "dynamic pressure," or the pressure formed by the winds produced by the shock front.

a. As the shock front expands into increasingly larger volumes of the medium, the peak incident pressure at the front decreases and the duration of the pressure increases.

b. If the shock wave impinges on a rigid surface oriented at an angle to the direction of propagation of the wave, a reflected pressure is instantly developed on the surface and the pressure is raised to a value that exceeds the incident pressure. The reflected pressure is a function of the pressure in the incident wave and the angle formed between the rigid surface and the plane of the shock front.

2. **Partially confined explosions**. When an explosion occurs within a structure, the peak pressure associated with the initial shock front will be extremely high and, in turn, will be amplified by reflections within the structure. In addition, the accumulation of gases from the explosion will exert additional pressures and increase the load duration within the structure. The combined effects of both pressures eventually may destroy the structure if it is not strengthened sufficiently or adequate venting for the gas and the shock pressure is not provided, or both. For structures that have one or more strengthened walls, venting for relief of excessive gas or shock pressures, or both, may be provided by means of openings in or frangible construction of the remaining walls or roof, or both. This type of construction will permit the blast wave from an internal explosion to spill over onto the exterior ground surface. These pressures, referred to as exterior or leakage pressures, once released from their confinement, expand radially and act on structures or persons, or both, on the other side of the barrier.

C. Expected effects - Hazard Division 1.1

1. **Conventional structures**. Conventional structures are designed to withstand roof snow loads of 30 pounds per square foot (1.44 kilopascals) and wind loads of 100 miles per hour (161

kilometers per hour). The loads equate to 0.2 pounds per square inch (psi). Airblast overpressure at Hazard Division 1.1 barricaded intraline distance is 12 psi (82.7 kPa); at unbarricaded intraline distance is 3.5 psi (24 kPa); and at inhabited building distance is 0.9 to 1.2 psi (6.2 to 8.3 kPa). Comparing these loads with the design capacity, it is evident that conventional buildings will be damaged even at inhabited building distance. Conventional structures, which include aboveground storage facilities, contribute little to propagation protection from either blast or fragments. Propagation protection is provided by distance and/or barricading. The amount of damage to be expected at various pressure levels is described below.

2. **Earth-covered magazines**. The earth-covered magazines identified in section B., Chapter 5, separated one from another by the minimum distances required by Table 9-5, provide virtually complete protection against propagation of explosion by blast, fragments, and fire; however, there may be some cracking of concrete barrels and rear walls, possible severe cracking and some spalling of front walls, and some damage to doors and ventilators.

3. **Underground storage facilities**. Underground facilities sited and constructed as specified in section G, Chapter 9 provide a high degree of protection against propagation of explosion between chambers by blast, fragments or spall, and between underground and aboveground structures. Delayed propagation between chambers by fire is possible, but this possibility may be minimized by installation of a fire suppression system.

4. **Barricaded open-storage modules**. Barricaded open-storage modules (subsection B.3., Chapter 5) provide a high degree of protection against propagation of explosion by blast and fragments. However, if flammable materials are present in nearby cells, subsequent propagation of explosion by fire is possible. Items at K=1.1 separations from a donor explosion will be covered with earth and unavailable for use until extensive uncovering operations and possibly maintenance are completed. Items at K=2.5 separations are expected to be readily accessible.

5. **Barricaded aboveground magazine distance - $6W^{1/3}$ ft ($2.4Q^{1/3}$m) - 27 psi (186.1 kPa)**

a. Unstrengthened buildings will be destroyed completely.

b. Personnel at this distance or closer will be killed by direct action of blast, by being struck by building debris, or by impact against hard surfaces.

c. Transport vehicles will be overturned and crushed by blast.

d. Explosives loaded vessels will be damaged severely, with propagation of explosion likely.

e. Aircraft will be destroyed by blast, thermal, and debris effects.

f. **Control**. Barricades are effective in preventing immediate propagation of explosion by low angle fragments, but provide only limited protection against delayed propagation of explosion caused by fire resulting from high angle firebrands.

6. **Barricaded intraline distance - $9W^{1/3}$ ft ($3.6Q^{1/3}$m) - 12 psi (82.7 kPa)**

a. Unstrengthened buildings will suffer severe structural damage approaching total destruction.

b. Severe injuries or death to occupants of the ES may be expected from direct blast, building collapse, or translation.

c. Aircraft will be damaged beyond economical repair both by blast and fragments. If the aircraft are loaded with explosives, delayed explosions are likely to result from subsequent fires.

d. Transport vehicles will be damaged heavily, probably to the extent of total loss.

e. Direct propagation of explosion between two explosives locations is unlikely when barricades are interposed between them to intercept high velocity low angle fragments.

f. Improperly designed barricades or structures may increase the hazard from flying debris, or may collapse in such a manner as to increase the risk to personnel and equipment.

g. **Control**. Barricading is required. Exposed structures containing equipment of high monetary value or of critical mission importance or wherein personnel exposure is significant may require hardening for necessary protection of personnel and equipment.

7. **Unbarricaded aboveground magazine distance - $11W^{1/3}$ ft ($4.4Q^{1/3}$m) - 8 psi (55.3 kPa)**

a. Unstrengthened buildings will suffer damage approaching total destruction.

b. Personnel are likely to be injured seriously due to blast, fragments, debris, and translation.

c. There is a 20-percent risk of eardrum rupture.

d. Explosives loaded vessels are likely to be damaged extensively and delayed propagation of explosion may occur.

e. Aircraft will be damaged heavily by blast and fragments; destruction by ensuing fire is likely.

f. Transport vehicles will sustain severe body damage, minor engine damage, and total glass breakage.

g. **Control**. Barricading will reduce significantly the risk of propagation of explosion and injury of personnel by fragments.

8. **Unbarricaded intraline distance - $18W^{1/3}$ ft ($7.2Q^{1/3}$m) - 3.5 psi (24 kPa)**

a. Direct propagation of explosion is not expected.

b. There is some possibility that delayed communication of an explosion may occur from fires, or as a result of equipment failure at the ES.

c. Damage to unstrengthened buildings will be of a serious nature and approximately 50 percent or more of the total replacement cost.

d. There is a 1-percent chance of eardrum damage to personnel.

e. Personnel injuries of a serious nature are likely from fragments, debris, firebrands, or other objects.

f. Cargo ships would suffer damage to decks and superstructure from being struck by fragments and having doors and bulkheads on the weather deck buckled by overpressure.

g. Aircraft can be expected to suffer considerable structural damage from blast. Fragments and debris are likely to cause severe damage to aircraft at distances calculated from the formula $18W^{1/3}$ when small quantities of explosives are involved.

h. Transport vehicles will incur extensive, but not severe, body and glass damage consisting mainly of dishing of body panels and cracks in shatter-resistant window glass.

i. **Control**. Many situations arise in which control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical. Use of such construction to withstand blast overpressure is encouraged if it is more economical than distance alone, or if sufficient distance is not available to prevent the overpressure from exceeding this level.

9. **Public traffic route distance (under 100,000 lbs HE) $24W^{1/3}$ ft ($9.6Q^{1/3}$m) - 2.3 psi (15.8 kPa)**

a. Unstrengthened buildings can be expected to sustain damage approximately 20 percent of the replacement cost.

b. Occupants of exposed structures may suffer temporary hearing loss or injury from secondary blast effects such as building debris and the tertiary effect of displacement.

c. Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and fragmentation characteristics thereof.

d. Vehicles on the road should suffer little damage unless hit by a fragment or unless the blast wave causes momentary loss of control.

e. Aircraft should suffer some damage to appendages and sheet metal skin from blast and possible fragment penetration; however, the aircraft should be operational with minor repair.

f. Cargo-type ships should suffer minor damage to deck structure and exposed electronic gear from blast and possible fragment penetration, but such damage should be readily repairable.

g. **Control**. The risk of injury or damage due to fragments for limited quantities of explosives at the PES can be reduced by barricading. Also, many situations arise when control of pressure by suitably designed suppressive construction at the PES or protective construction at the ES are practical.

10. **Public traffic route distance (over 250,000 lbs HE) $30W^{1/3}$ ft ($12Q^{1/3}$m) - 1.7 psi (11.7 kPa)**

a. Unstrengthened buildings can be expected to sustain damage approximately 10 percent of the replacement cost.

b. Occupants of exposed unstrengthened structures may suffer injury from secondary effects such as building debris.

c. Aircraft in landing and takeoff status may lose control and crash.

d. Parked military and commercial aircraft likely will sustain minor damage due to blast but should remain airworthy.

e. Personnel in the open are not expected to be killed or seriously injured directly by blast. There may be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and fragmentation characteristics thereof.

f. **Control**. The risk of injury or damage due to fragments for limited quantities of explosives at the PES may be reduced by barricading or application of minimum fragment distance requirements.

11. **Inhabited building distance $40W^{1/3}$ ft - $50W^{1/3}$ ft ($16Q^{1/3}$ - $20Q^{1/3}$m) - 1.2 psi - 0.90 psi (8.3 kPa - 6.2 kPa)**

a. Unstrengthened buildings can be expected to sustain damage up to about 5 percent of the replacement cost.

b. Personnel in buildings are provided a high degree of protection from death or serious injury, with injuries that do occur principally being caused by glass breakage and building debris.

c. Personnel in the open are not expected to be injured seriously directly by the blast. There could be some personnel injuries caused by fragments and debris, depending largely upon the PES structure and amount of ammunition and the fragmentation characteristics thereof.

d. **Control**. Glass breakage and structural damage can be reduced by means such as orientation, by keeping the surface area of exposed glass panels to a minimum and the use of blast-resistant windows.

12. **Airblast effects on personnel**. The following describes airblast over-pressure effects to personnel.

Effect	Dose (psi)
1 percent Eardrum Rupture	3.4
50 percent Eardrum Rupture	16
Threshold Lung Rupture	10 (50 msec duration) 20-30 (3 msec duration)
1 percent Mortality	27 (50 msec duration) 60-70 (3 msec duration)

D. Permissible exposures to airblast overpressure - Hazard Division 1.1

1. **12 psi (82.7 kPa) at $9W^{1/3}$ ($3.6Q^{1/3}$)**. (Barricading is required.)

a. Buildings housing successive steps of a single production, renovation, or maintenance operation.

b. Security alert force buildings.

c. Facilities of a tactical missile site where greater distances from the PES cannot be provided for technical reasons.

d. Breakrooms and change houses if they are part of an operating line and are used exclusively by personnel employed in operations of the line.

e. Temporary holding areas for trucks or railcars containing explosives to service production or maintenance facilities.

f. Field operations in magazine areas when performing minor maintenance, preservation, packaging, or surveillance inspection.

g. Unmanned auxiliary power facilities, transformer stations, water treatment and pollution abatement facilities, and other utility installations that serve the PES and are not an integral function in the PES, and loss of which would not create an immediate secondary hazard. These applications need not be barricaded. Exception: Unmanned auxiliary power generation or conversion facilities exclusively supplying power to the explosive storage area and security fence lighting may be located at fire protection distance from explosive facilities (50 feet for fire-resistant structures, 100 feet for nonfire-resistant structures).

h. Dunnage preparation and similar support structures housing non-explosives operations if used only by personnel employed at the PES.

i. Service magazines that are part of operating lines. Distances are based on the quantity and type of ammunition or explosives in the service magazine or magazines, not the operating building.

j. Exposures as indicated in the next paragraph if blast suppression and structure hardening provide comparable protection for personnel and equipment involved.

2. **3.5 psi (24 kPa) at $18W^{1/3}$ ($7.2Q^{1/3}$)**

a. Surveillance, maintenance, and inspection buildings and labor intensive operations closely related to the PES.

b. Comfort, safety, and convenience occupied buildings exclusively in support of the PES (such as lunchrooms, motor pools, area offices, auxiliary fire stations, transportation dispatch points, and shipping and receiving buildings (not magazine area loading docks)).

c. Parallel operating lines from one another, whether or not barricaded, provided ammunition and explosives involved in each operating line present similar hazards. The criticality or survivability of one or more of the operating lines may require that each line be given an inhabited building level of protection.

d. Operations and training functions that are manned or attended exclusively by personnel of the unit operating the PES. This includes day rooms, squadron operation offices, and similar functions for units such as individual missile firing batteries, aircraft squadrons, or ammunition supply companies. Training functions permitted this level of exposure (3.5 psi) include organized

classroom and field training of personnel who may be required to engage in explosives work at the PES. Maneuver areas, proving ground tracks, and similar facilities for armored vehicles also may be exposed to 3.5 psi (24 kPa) since the vehicle should provide adequate protection to the operators from fragments and debris.

e. Maintenance of military vehicles and equipment when the PES is basic load or ready storage located outside the continental United States (OCONUS) areas, and is limited to 8,820 lb (4,000 kg) or less net explosive quantity (NEQ) at each and when the maintenance work is performed exclusively by and for military personnel of the unit for which the basic load of ammunition is stored.

f. Auxiliary power and utilities functions excluding "cold-iron" facilities, supply, and mechanical support at naval station waterfront areas when not continuously manned, when serving only the waterfront area, and when the PES is a ship or ammunition handling location on the waterfront. This category includes auxiliary power plants; compressor stations; electric power transformers; tool and consumable supplies storage and issue; and handling equipment service, battery charging, and minor repair. When such facilities serve an entire naval station or base complex, or when loss of the facility will cause an immediate loss of vital function, the exposure level must not exceed 1.2 psi (8.3 kPa).

g. Minimum distance between separate groups of explosives loaded combat-configured aircraft or between aircraft and a pre-load or "quick-turn"site that serves to arm the aircraft. The use of intervening barricades is required to reduce further communication and fragment damage and eliminate the necessity for totaling net explosive weight (NEW). Loading ammunition and explosives aboard aircraft can be accomplished with each group of aircraft without additional protection.

h. Service magazines that are part of operating lines. Distances are based on quantity and type of ammunition or explosives in the service magazines, not the operating building.

i. Container stuffing and unstuffing operations that are routine support of PES. This applies only to main support functions set aside for support of ship-loading or manufacturing operations. When the activity is in connection with ship-loading and unloading and the ES is an ammunition ship, the quantity at the container site shall govern. (Container stuffing and unstuffing in a magazine area are permitted at intermagazine distances.)

j. Between explosive-loaded combat aircraft and those nonexplosives facilities that directly support the servicing and launching of a unit's armed aircraft (that is, activities and their operating facilities that handle ammunition and explosives on the flightline, prepare and service armed aircraft, and those that fly combat aircraft). Direct flightline combat aircraft associated facilities may contain field offices, breakrooms, unit training rooms, and equipment and supply rooms, as well as petroleum, oils, lubricants (POL) hydrant facilities and civil engineer (CE) fire protection stations. Specifically excluded are morale, welfare, and recreation (MWR) facilities; base civil engineering headquarters; industrial facilities, including central base supply.

3. **2.3 psi (15.8 kPa) at $24W^{1/3}$ ($9.6Q^{1/3}$).** Personnel exposed to remotely controlled operations.

4. **2.3-1.7 psi (15.8-11.7 kPa) at $24\text{-}30W^{1/3}$ ($9.6\text{-}12Q^{1/3}$)**

a. Public traffic routes with medium and low traffic densities as described in E.2.c. (3) (b) and (c), below.

b. Open-air recreation facilities where structures are not involved (such as ball diamonds and volleyball courts) used for morale and health purposes at posts, camps, naval stations, air bases, and other operational military activities. When recreation facilities solely are for off-duty military personnel at their posts of duty, neither blast nor fragment Q-D apply. This total relaxation of Q-D requirements applies only when the PES and the ES are related closely as with a security alert force and explosives facilities for which they are responsible. It is not intended that this relaxation be used to encourage the building of elaborate installations that substitute for properly located R&R facilities or that they encourage the colocation of essentially unrelated military functions.

c. Training areas for unprotected military personnel. They include observation points and instruction areas for small arms and artillery firing ranges and similar fixed facilities, including small classrooms, designed for occasional use coincident with use by groups or classes using the range. The separation or other protection is required from permanent magazines and ammunition supply points but not from that ammunition and explosives needed for any particular exercise in order to achieve realism in training nor from explosives in necessary on-the-job training operations for explosives workers.

d. Aircraft passenger loading and unloading areas that do not include any structures.

5. **1.7 psi (11.7 kPa) at $30W^{1/3}$ ($12Q^{1/3}$)**. Combat aircraft parking areas exposed to ammunition and explosive storage and operating facilities.

6. **1.2 - 0.90 psi (8.3 - 6.2 kPa) at $40\text{-}50W^{1/3}$ ($16\text{-}20Q^{1/3}$)**

a. Inhabited buildings, administrative and housing areas.

b. Installation boundaries, unless manifestly inapplicable (unsuitable terrain, government land not open to the public, and so forth). For locations where installation boundary lines are penetrated by inhabited building Q-D arcs, the Service shall certify that conditions do not exist for the application of inhabited building protection to the encumbered area and shall establish procedures to monitor the area for any change in that status.

c. Athletic fields and other recreation areas when structures are present.

d. Flight-line passenger service functions.

e. Main power houses providing vital utilities to a major portion of an installation.

f. Storehouses and shops that by reason of their vital strategic nature, or high intrinsic value of their contents, should not be placed at risk.

g. Functions that, if momentarily put out of action, would cause an immediate secondary hazard by reason of their failure to function.

h. Public traffic routes with high traffic density as described in E.2.c. (3) (a), below.

E. Fragments

1. General

a. An important consideration in the analysis of the hazard associated with an accidental explosion is the effect of the fragments generated by the explosion. These fragments are known as primary or secondary fragments depending on their origin.

b. Primary fragments are formed as a result of the shattering of the explosive container. The container may be the casing of conventional munitions, the kettles, hoppers, and other metal containers used in the manufacture of explosives; the metal housing of rocket engines; and similar items. These fragments usually are small in size and travel initially at velocities of the order of thousands of feet per second.

c. Secondary fragments are formed as a result of high blast pressures on structural components and items in close proximity to the explosion. These fragments are somewhat larger in size than primary fragments and travel initially at velocities in the order of hundreds of feet per second.

d. A hazardous fragment is one having an impact energy of 58 ft-lb (79 joules) or greater.

2. **Minimum fragment distances**

a. Minimum fragment distances are to protect personnel in the open; firebrand distance minima are to protect facilities. The larger of those distances will be applied to:

(1) Installation boundaries, unless manifestly inapplicable (unsuitable terrain, government land not open to the public, and so forth). For locations where installation boundary lines are penetrated by inhabited building Q-D arcs, the Service shall certify that conditions do not exist for the application of inhabited building protection to the encumbered area and shall establish procedures to monitor the area for any change in that status.

(2) Administration and housing areas.

(3) Athletic and other recreation areas except as described below.

(4) Flight-line passenger service functions.

(5) Main powerhouses providing vital utilities to a major portion of the installation.

(6) Storehouses and shops that by reason of their vital, strategic nature, or the high intrinsic value of their contents, should not be placed at risk.

(7) Functions that, if momentarily put out of action, will cause an immediate secondary hazard by reason of their failure to function.

(8) Private vehicles parked in administrative areas.

b. Examples when minimum fragment and firebrand distances need not be applied are:

(1) Recreation or training facilities if these facilities are for the exclusive use of personnel assigned to the PES.

(2) Related and support DoD-controlled functions for which intermagazine and intraline distances are the usual protection levels.

(3) Maintenance, supply, and training facilities, and operations offices for the service of the logistics and operations functions of combat aircraft, Army battalion-size or smaller

delivery or ammunition supply units, separate air defense firing batteries, or a single pier or wharf for which the ammunition in the PES is intended.

(4) Between PES and relatively static inert storage areas, including parking areas for dead storage of military aircraft or vehicles.

(5) Between facilities in an operating line; between operating lines; and between operating lines and storage locations that normally are separated by inhabited building distances to protect workers and insure against interruption of production.

c. The minimum distance for protection from hazardous fragments shall be based on primary and secondary fragments from the PES and the population and/or traffic density of the ES. Secondary fragments include debris such as that from structural elements of the facility and from non-confining process equipment likely to rupture into enough pieces to significantly contribute to the total number of expected fragments. Primary fragments include items such as those discussed in paragraph E.1.b., above, and those from items listed in Table 9-2. DDESB approved analyses and/or approved tests may be used to determine minimal distances for both primary and secondary fragments. DDESB Technical Paper No. 13 (reference (b)) is an example of a method to determine minimal distances for building debris. In the absence of appropriate analyses and/or tests, default hazardous debris distances defined below apply.

(1) For populous locations, i.e., those areas and/or functions identified in subsection D.6., above, where military, civilian employees, dependent and/or public personnel are located, the minimum distance shall be that distance at which fragments, including debris from structural elements of the facility or process equipment, shall not exceed a hazardous fragment density of one hazardous fragment per 600 ft^2 (56 m^2). If this distance is not known, the following shall apply:

(a) For 100 lbs NEW (45 kg NEQ) or less of demolition explosives, thin-cased or low fragmentation ammunition items, bulk high explosives, pyrotechnics, and in-process explosives of Hazard Division 1.1, the minimum distance to exposures listed in paragraph E.2.a., above, shall be 670 ft (204 m). In the application of this paragraph, alternative distances based on hazards analysis may be used when approved by DDESB.

(b) For all types of Hazard Division 1.1 in quantities of 101 to 30,000 lbs NEW (46 to 13,600 Kg NEQ), the minimum distance shall be 1250 ft (380 m), unless it may be shown that fragments and debris from structural elements of the facility or process equipment shall not present a hazard beyond the distance specified in Table 9-1. For items that have been evaluated adequately, a different minimum distance such as in Table 9-2 may be used. (Facilities sited at 1,235 or 1,245 ft in accordance with past standards shall be considered to be in compliance with the 1,250 ft (380 m) minimum requirement.)

(2) For sparsely populated locations, i.e., those populous locations where the personnel exposure is no greater than addressed in subparagraph E.2.c.(2)(a) below, the minimum 1,250 ft (380 m) fragment distance may be reduced to 900 ft (270 m) if certain specific conditions exist as follows:

(a) No more than 25 persons are located in any sector bounded by the sides of a 45 degree angle, with the vertex at the PES, and the 900 ft (270 m) and 1,250 ft (380 m) arcs from the PES.

(b) The NEW of the PES does not exceed 11,400 lbs (5,170 kg).

(3) For public traffic routes, the minimum fragment and debris distance for Hazard Division 1.1 ammunition and explosives shall be based on the traffinc density considered at three levels: high traffic density, medium traffic density, and low traffic density. The traffic density shall be averaged over a normal (non-holiday) week in terms of number of passengers during a 24-hour period. Minimum fragment distance reductions based on sparse population considerations addressed in subparagraph E.2.c. (2), above, do not apply to public traffic routes.

Note: In applying criteria other than the default values given in subparagraphs E.2.c (3) (a), (b) and (c), below (which are based on car (and rail) speed of 50 mile/hour (80 km/hour), and a ship speed of 10 mile/hour (16 km/hour)), considerations such as the following shall be taken into account to establish acceptable exposure: speed of vehicles, number of passengers per vehicle, protection afforded by the vehicle, variation in daily traffic levels in relation to explosives activities, and seasonal traffic trends. The default value of two passengers per car may be used to estimate traffic density.

(a) **High traffic density**. If routes have 10,000 or more car and/or rail passengers per day, or 2,000 or more ship passengers per day, then inhabited building distance criteria apply (subparagraph E.2.c. (1), above).

(b) **Medium traffic density**. If routes have 400 or more, but less than 10,000 car and/or rail passengers per day, or 80 or more, but less than 2,000 ship passengers per day, then 60% of the specified minimum fragment distance for inhabited building distance applies. Medium traffic density criteria for minimum fragment distance apply, as a minimum, to recreational activity that is extensive and occurs on a regular basis.

(c) **Low traffic density**. If routes have less than 400 cars and/or rail passengers per day, or less than 80 ship passengers per day, then no minimum fragment distance is required. Minimum distance shall be based on blast criteria (K24/K30) only (subsection D.4., above).

(4) For other exposures that are permitted at public traffic route separation distances (subsections D.3., D.4. and D.5., above), fragment and debris distance minima for Hazard Division 1.1 ammunition and explosives shall be at least 60% of the specified minimum fragment distance for inhabited building distance.

F. Thermal hazard

1. **General**. The energetic materials used by Department of Defense all produce an exothermic reaction defined either as a deflagration or a detonation. A deflagration is an exothermic reaction that propagates from the burning gases to the unreacted material by conduction, convection, and radiation. In this process, the combustion zone progresses through the material at a rate that is less than the velocity of sound in the unreacted material. In contrast, a detonation is an exothermic reaction that is characterized by the presence of a shock wave in the material that establishes and maintains the reaction. A distinctive difference is that the reaction zone propagates at a rate greater than sound velocity in the unreacted material. Every material capable of detonating has a characteristic velocity that is under fixed conditions of composition, temperature, and density.

2. **Permissible exposures**. Personnel shall be provided protection that will limit thermal fluxes to 0.3 calories per square centimeter per second (12.56 kilowatts per square meter) when hazard assessments indicate the probability of accidental explosions is above an acceptable risk level as determined on a case-by-case basis by the DoD Component concerned.

G. Ground shock

1. **General**. Ground shock from explosions in underground facilities may endanger assets in neighboring chambers and produce damage to buildings on the surface. Protection of assets can be achieved by proper chamber separation distance and design. Distance requirements to protect surface structures are dependent upon site specific geological conditions, as well as NEW and chamber loading density. Chapter 9 details quantity distance requirements for ground shock protection from explosions in underground facilities.

2. **Permissible exposures**. Procedures for predicting ground shock and calculating Q-D to protect facilities are in Chapter 9.

H. Chemical agent hazards.

These items are in Chapter 11.

CHAPTER 3

HAZARD CLASSIFICATION AND COMPATIBILITY GROUPS

A. Classification system

1. To ease identification of hazard characteristics and thus promote safe storage and transport of ammunition and explosives, the Department of Defense shall use the international system of classification devised by the United Nations Organization (UNO) for transport of dangerous goods. Ammunition and explosives also will be assigned the appropriate Department of Transportation (DOT) class and marking in accordance with 49 CFR 173 (reference (c)).

2. The UNO classification system consists of nine hazard classes, two of which are applicable to ammunition and explosives as defined in this Standard, Classes 1 and 6, (See ST/SG/AC.10/1/Rev. 9 (reference (d))). Thirteen compatibility groups are included for segregating ammunition and explosives on the basis of similarity of characteristics, properties, and accident effects potential.

3. Class 1 is divided into divisions that indicate the character and predominance of associated hazards:

a. Mass-detonating (Division 1).

b. Non-mass detonating fragment producing (Division 2).

c. Mass fire (Division 3).

d. Moderate fire-no blast (Division 4).

e. Very insensitive explosives (Division 5).

f. Extremely insensitive ammunition (Division 6).

This Standard uses the term "Hazard Division" instead of "Division", both to emphasize the correspondence with the previous term "Hazard Class" and to avoid the cumbersome alternatives "Division 1 of Class 1," and so forth. For further refinement of this hazard identification system, a numerical figure (in parenthesis) is used to indicate the minimum separation distance (in hundreds of feet) for protection from debris, fragments, and firebrands when distance alone is relied on for such protection. This number is placed to the left of the Hazard Division designators 1.1 through 1.3, such as (18)1.1, (08)1.2, and (02)1.3.

4. Articles that contain riot control substance without explosives components are classified as Class 6, Division 1, in the UNO Recommendations for Transport of Dangerous Goods. For DoD purposes, these articles are considered as Hazard Division 1.4 and may be stored in limit quantities with other base defense munitions. Bulk agent is also Hazard Division 6.1 in the UNO recommendations.

B. Storage principles

1. The highest degree of safety in ammunition and explosives storage could be assured if each item or division were stored separately. However, such ideal storage generally is not

feasible. A proper balance of safety and other factors frequently requires mixing of several types of ammunition and explosives in storage.

2. Ammunition and explosives may not be stored together with dissimilar materials or items that present positive hazards to the munitions. Examples are mixed storage of ammunition and explosives with flammable or combustible materials, acids, or corrosives.

3. Different types, by item and division, of ammunition and explosives may be mixed in storage provided they are compatible. Ammunition and explosives are assigned to a compatibility group (CG) when they can be stored together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident. Considerations that were used in developing the CGs included but were not limited to:

a. Chemical and physical properties.

b. Design characteristics.

c. Inner and outer packing configurations.

d. Quantity-distance (Q-D) division.

e. Net explosive weight (NEW).

f. Rate of deterioration.

g. Sensitivity to initiation.

h. Effects of deflagration, explosion, or detonation.

4. Subject to application of these standards and particularly to compatibility as defined herein, ammunition and explosives shall be mixed in storage when such mixing will facilitate safe operations and promote overall storage efficiency. Assignment of items to CGs requiring separate storage shall be minimized consistent with actual hazards presented and not based on administrative considerations or end use.

5. As used in this Standard, the phrase "with its own means of initiation" indicates that the ammunition has its normal initiating device assembled to it and this device is considered to present a significant risk during storage. However, the phrase does not apply when the initiating device is packaged in a manner that eliminates the risk of causing detonation of the ammunition in the event of accidental functioning of the initiating device, or when fuzed end items are so configured and packaged as to prevent arming of the fuzed end items. The initiating device may even be assembled to the ammunition provided its safety features preclude initiation of detonation of the explosives filler of the end item in the event of an accidental functioning of the initiating device.

C. Compatible ammunition and explosives

1. Different kinds of explosives may be stored together. However, items in one of the three groups listed below are not necessarily compatible with items in another of the groups:

a. The various kinds of initiating explosives are compatible one with another.

b. The various kinds of propellants are compatible one with another regardless of Q-D division.

c. The various kinds of high explosives (HEs) are compatible one with another.

2. Different types of ammunition within any one of the following seven groups are compatible and may be stored together:

a. All types of initiating devices.

b. All types of HE ammunition without their own means of initiation and without a propelling charge.

c. All types of HE ammunition without their own means of initiation and with a propelling charge.

d. All types of HE ammunition with their own means of initiation, with or without propelling charge.

e. All pyrotechnics and all types of ammunition containing both explosives and illuminating, incendiary, smoke, or tear-producing agents except:

(1) Water activated pyrotechnics and ammunition.

(2) Ammunition containing white phosphorus (WP), flammable liquids, or gas.

f. All types of ammunition containing both explosives and WP.

g. All types of ammunition containing both explosives and flammable liquids or gels.

3. Ammunition items in one of the groups in subsection C.2., above, generally are not compatible with items in other groups.

4. Bulk propellants and explosives may be stored with ammunition containing like materials:

a. Bulk propellants are compatible with propelling charges without projectiles, and cartridges with solid or inert projectiles.

b. Bulk HE are compatible with HE ammunition without its own means of initiation and without a propelling charge.

5. Ammunition and explosives in substandard or damaged packaging, in a suspect condition, or with characteristics that increase the risk in storage, are not compatible with other ammunition and explosives and shall be stored separately.

D. Storage and compatibility groups (CGs)

In view of ammunition and explosives storage principles and the considerations for mixed storage, ammunition and explosives are assigned to the appropriate one of 13 CGs (A through H, J, K, L, N, and S).

1. **Group A.** Initiating explosives. Bulk initiating explosives that have the necessary sensitivity to heat, friction, or percussion to make them suitable for use as initiating elements in an explosive train. Examples are wet lead azide, wet lead styphnate, wet mercury fulminate, wet tetracene, dry cyclonite (RDX), and dry pentaerythritol tetranitrate (PETN).

2. **Group B.** Detonators and similar initiating devices not containing two or more independent safety features. Items containing initiating explosives that are designed to initiate or

continue the functioning of an explosive train. Examples are detonators, blasting caps, small arms primers, and fuzes.

3. **Group C**. Bulk propellants, propelling charges, and devices containing propellant with or without their means of ignition. Items that upon initiation will deflagrate, explode, or detonate. Examples are single-, double-, triple-base, and composite propellants, rocket motors (solid propellant), and ammunition with inert projectiles.

4. **Group D**. Black powder, HE, and ammunition containing HE without its own means of initiation and without propelling charge, or a device containing an initiating explosive and containing two or more independent safety features. Ammunition and explosives that can be expected to explode or detonate when any given item or component thereof is initiated except for devices containing initiating explosives with independent safety features. Examples are bulk trinitrotoluene (TNT), Composition B, black powder, wet RDX or PETN, bombs, projectiles, cluster bomb units (CBUs), depth charges, and torpedo warheads.

5. **Group E**. Ammunition containing HE without its own means of initiation and containing or with propelling charge (other than one containing a flammable or hypergolic liquid). Examples are artillery ammunition, rockets, or guided missiles.

6. **Group F**. Ammunition containing HE with its own means of initiation and with propelling charge (other than one containing a flammable or hypergolic liquid) or without a propelling charge.

7. **Group G**. Fireworks, illuminating, incendiary, and smoke, including hexachlorethane (HC) or tear producing munitions other than those munitions that are water activated or which contain WP or flammable liquid or gel. Ammunition that, upon functioning, results in an incendiary, illumination, lachrymatory, smoke, or sound effect. Examples are flares, signals, incendiary or illuminating ammunition, and other smoke or tear producing devices.

8. **Group H**. Ammunition containing both explosives and WP or other pyrophoric material. Ammunition in this group contains fillers which are spontaneously flammable when exposed to the atmosphere. Examples are WP, plasticized white phosphorus (PWP), or other ammunition containing pyrophoric material.

9. **Group J**. Ammunition containing both explosives and flammable liquids or gels. Ammunition in this group contains flammable liquids or gels other than those which are spontaneously flammable when exposed to water or the atmosphere. Examples are liquid- or gel-filled incendiary ammunition, fuel-air explosive (FAE) devices, flammable liquid-fueled missiles, and torpedoes.

10. **Group K**. Ammunition containing both explosives and toxic chemical agents. Ammunition in this group contains chemicals specifically designed for incapacitating effects more severe than lachrymation. Examples are artillery or mortar ammunition (fuzed or unfuzed), grenades, and rockets or bombs filled with a lethal or incapacitating chemical agent (see note 4, Table 3-1).

11. **Group L**. Ammunition not included in other compatibility groups. Ammunition having characteristics that do not permit storage with other types of ammunition, or kinds of explosives, or dissimilar ammunition of this group. Examples are water-activated devices, prepackaged

hypergolic liquid-fueled rocket engines, certain FAE devices, triethyl aluminum (TEA), and damaged or suspect ammunition of any group. Types presenting similar hazards may be stored together but not mixed with other groups.

12. **Group N.** Hazard Division 1.6 ammunition containing only extremely insensitive detonating substance (EIDS). Examples are bombs and warheads. If dissimilar Group N munitions, such as Mk 82 and Mk 84 Bombs, are mixed together and have not been tested to assure non-propagation; the mixed munitions are considered to be Hazard Division 1.2, Compatibility Group D for purposes of transportation and storage.

13. **Group S.** Ammunition presenting no significant hazard. Ammunition so packaged or designed that any hazardous effects arising from accidental functioning are confined within the package unless the package has been degraded by fire, in which case all blast or projection effects are limited to the extent that they do not hinder firefighting significantly. Examples are thermal batteries, explosive switches or valves, and other ammunition items packaged to meet the criteria of this group.

E. Mixed storage

1. Except as noted in subsection E.2. below, ammunition and explosives of different compatibility groups may only be mixed in storage as indicated in Table 3-1.

2. Certain continental United States (CONUS) locations that are designated by a DoD Component, and site approved by the DDESB, to store ammunition and explosives packaged in configurations for rapid response; e.g., Rapid Deployment Force, are authorized to mix compatibility groups as required to achieve the optimum load needed by the receiving troops. The maximum credible event at any of these storage sites shall be limited to 8820 lbs NEW (4000 kg NEQ).[1] For the determination of the NEW at above grade storage sites, the following explosives shall be excluded:

a. Propelling charges in Hazard Division 1.2 fixed, semifixed, mortar, and rocket ammunition.

b. The quantity of explosives in Hazard Division 1.3 items, unless the site contains only Hazard Division 1.3, in which case Hazard Division 1.3 Q-D apply. In the application of this paragraph to separate loading ammunition, an equal number of propelling charges may be stored with the separate loading projectiles.

3. The Q-D requirements in Chapter 9 shall be applied to the storage locations addressed in subsection E.2., above.

[1] See Chapter 10 for application.

Table 3-1. Storage Compatibility Mixing Chart.

Groups	A	B	C	D	E	F	G	H	J	K	L	N	S
A	X	Z											
B	Z	X	Z	Z	Z	Z	Z					X	X
C		Z	X	X	X	Z	Z					X	X
D		Z	X	X	X	Z	Z					X	X
E		Z	X	X	X	Z	Z					X	X
F		Z	Z	Z	Z	X	Z					Z	X
G		Z	Z	Z	Z	Z	X					Z	X
H								X					X
J									X				X
K										Z			
L													
N		X	X	X	X	Z	Z					X	X
S		X	X	X	X	X	X	X	X			X	X

Notes:

1 The marking "X" at an intersection of the above chart indicates that these groups may be combined in storage. Otherwise, mixing is either prohibited or restricted according to Note 2, below.

2 The marking "Z" at an intersection of the above chart indicates that when warranted by operational considerations or magazine nonavailability, and when safety is not sacrificed, logical mixed storage of limited quantities of some items of different groups may be approved. These relaxations involving mixed storage shall be approved by the DoD Component and are not considered waivers. Combinations that violate the principles of subsection B.3., above, require justification by a waiver or exemption. Items from Group B or Group F shall be segregated from articles of other compatibily groups by means that prevent propagation of fire or detonation.

Examples of acceptable combinations are:

a. Hazard Division 1.1, Group A, initiating explosives with Hazard Division 1.1, Group B, fuzes not containing two or more independent safety features.

b. Hazard Division 1.3, Group C, bulk propellants or bagged propelling charges with Hazard Division 1.3, Group G, pyrotechnics, without their own means of initiation.

3 Equal numbers of separately packaged components of complete rounds of any single type of ammunition may be stored together. When so stored, compatibility is that of the assembled round, that is, WP filler in Group H, HE filler in Groups D, E, or F, as appropriate.

4 Group K requires not only separate storage from other groups, but also may require separate storage within the group. The controlling DoD Component shall determine which items under Group K may be stored together and those which must be stored separately.

Notes for Table 3-1, continued:

5 Ammunition items without explosives that contain substances properly belonging to another U.N. hazard class may be assigned to the same compatibility group as items containing explosives and the same substance, and be stored with them.

6 DoD Components may authorize ammunition designated "Practice" by National Stock Number (NSN) and nomenclature to be stored with the fully loaded ammunition it simulates.

7 DoD Components may authorize the mixing of compatibility groups, except items in Groups A, K and L in limited quantities (generally 1000 lbs or less).

8 For purposes of mixing, all items must be packaged in approved storage/shipping containers. Items shall not be opened for purposes of issuing unpackaged munitions in storage locations. Outer containers may be opened in storage locations for purposes of inventorying; for removing munitions still inside an approved inner package in limited amounts; and for magazines storing only Hazard Division 1.4 items, unpacking inspecting, and repacking the Hazard Division 1.4 ammunition.

9 When using the "Z" mixing authorized by Note 2, articles of either compatibility Group B or F, each shall be segregated in storage from articles of other compatibility groups by means that prevent the propagation of Group B or F articles to articles of other compatibility groups.

10 If dissimilar Hazard Division 1.6, Group N munitions, such as Mk 82 and Mk 84 Bombs, are mixed together and have not been tested to assure non-propagation; the mixed munitions are considered to be Hazard Division 1.2, Compatibility Group D for purposes of transportation and storage. When mixing Group N munitions with Groups B through G, see Chapter 9, paragraphs B.1.h. through B.1.j. about changing Q-D hazard divisions.

F. Underground storage

Ammunition with smoke producing, incendiary, flammable liquid or toxic chemical agent fillers may be stored in single chamber underground facilities, but shall not be stored in multi-chamber facilities. Other than this restriction, ammunition and explosives of all compatibility groups may be placed in underground storage in compatible combinations as permitted above.

G. Explosives hazard classification procedures

DoD Explosives Hazard Classification Procedures (DLAR 8220.1, TB 700-2, NAVSEAINST 8020.8A, and TO 11A-1-47, reference (e)) shall be used as a basis for assignment of hazard divisions to all ammunition and explosives except those that are candidates for designation as extremely insensitive detonating substances (EIDS) and EIDS ammunition. EIDS and EIDS ammunition shall be assigned to hazard divisions as indicated in section L., below.

H. EIDS and EIDS ammunition

1. EIDS comprises Hazard Division 1.5 type explosive substances that, although mass detonating, are so insensitive that there is negligible probability of initiation or transition from burning to detonation in storage.

2. EIDS ammunition, Hazard Division 1.6, is ammunition that contains EIDS and that has demonstrated through test results (section L., below) that the mass and confinement effects of the

ammunition case are negligible on the probability of initiation or transition from burning to detonation of the EIDS in transport or storage. Such ammunition when intentionally initiated will be incapable of transferring detonation to another (that is, propagating).

I. Test procedures documents

ST/SG/AC.10/11/Rev. 2 (reference (f)) sets forth procedures to be used in the EIDS and EIDS ammunition (Hazard Division 1.6) testing required by sections J. through L., below.

J. Screening tests for EIDS

Substances that are candidates for the designation as EIDS shall be subjected to the screening tests given by Test Series 3 in DLAR 8220.1, TB 700-2, NAVSEAINST 8020.8A, TO 11A-1-47 (reference (e)) and specified in Table 3-2. Failure to achieve required results in a single test disqualifies the substance as a candidate EIDS.

Table 3-2. Test Procedures.

Test	Test Procedure Number	Required Results
Bureau of Explosives Machine Test	3(a)(i)	Pass drop height of 101.6 mm (4.0 in)
ABL Friction Test	3(b)(iii)	No reaction
Thermal Stability Test at 75°C	3(c)	No reaction
Small Scale Burning Test	3(d)(i)	No detonation or explosion

K. Required tests for EIDS

Substances judged on the basis of screening test results stated in section J, above, to be legitimate candidates for designation as EIDS shall be subjected to tests specified in Table 3-3. Required results for all tests as stated shall be achieved for designation as EIDS.

Table 3-3. EIDS Tests.

Test	UN Test Number [1]	No. of Trials	Sample	Failure Criteria
EIDS Cap	7(a)	3	80 mm diameter 160 mm length	Detonation
EIDS Gap	7(b)	3	73 mm diameter 280 mm length	Detonation
Susan Impact	7(c)(i)	5	51 mm diameter 102 mm length	≥27kPa at 3.05 m for 333 m/s impact
EIDS Bullet Impact	7(d)(i)	6	45 mm diameter 200 mm length	Explosion or detonation
EIDS External Fire	7(e)	3	45 mm diameter 200 mm length 5 samples/test	Detonation and/or >15 m debris throw
EIDS Slow Cook-off	7(f)	3	45 mm diameter 200 mm length	Detonation and or >3 fragments

Note 1 Detailed test descriptions are provided in *Recommendations on the Transport of Dangerous Goods, Tests and Criteria* (reference (f)).

L. Required tests for EIDS ammunition (Hazard Division 1.6)

To be classified as EIDS ammunition, ammunition containing EIDS in storage and/or transport configuration must be subjected to tests specified in Table 3-4 and achieve required results for all tests as stated. In addition, it must be demonstrated by actual test that intentional detonation of one item will be incapable of propagating detonation to another like item.

Table 3-4. EIDS Ammunition (Hazard Division 1.6) Tests.

Test	UN Test No[1]	No of Trials	Stimulus	Failure Criteria
1.6 Article External Fire	7(g)	1	3 or more articles in open wood or fuel fire	Hazard Division 1.1, 1.2 or 1.3 response
1.6 Article Slow Cook-off	7(h)	2	Gradually increasing thermal environment up to 365°C	No reaction more severe than burning[2]
1.6 Article Bullet Impact	7(j)	3	0.50 cal AP ammo fired at service velocity in 3-round burst	Detonation
1.6 Article Stack Test	7(k)[3]	3	Detonate all-up article in shipping or storage configuration containing 3 or more rounds	No propagation of detonation

Notes:

1 Detailed test descriptions are provided in *Recommendations on the Transport of Dangerous Goods, Tests and Criteria* (reference (f)).

2 The energetic material may ignite and burn and the case may melt or weaken sufficiently to allow mild release of combustion gases. Case closures may be thrown no more than 15 m.

3 U.S. implementation of the test requires confinement equivalent to the more severe conditions of storage or transport configuration for two tests. One test is conducted without confinement to allow collections of fragment and airblast data.

M. Hazard classification and compatibility groups

Table 3-5 provides examples of the relationship between compatibility groups, Q-D divisions, and DOT classes for items classified in accordance with DLAR 8220.1, TB 700-2, NAVSEAINST 8020.8A, TO 11A-1-47 (reference (e)). Table 3-6 assigns Q-D divisions and CGs to substances qualified as EIDS under the provisions of section K., above, and ammunition qualified as EIDS ammunition under provisions of section L., above.

N. Classes 1 or 6 chemical agent hazards or combined chemical agent and explosives hazards

Items in these classes are chemical agent-filled ammunition, chemical agents, and chemical agent-filled components. Depending upon the type of agent, its persistency, toxicity, or other characteristics, the primary safety consideration may be the area of agent dispersal rather than blast or fragment distance that usually control in the case of other ammunition. Items that contain only toxic chemical components are assigned to Hazard Division 6.1. Items that contain both explosives and toxic chemical components are assigned to Hazard Divisions 1.1 through 1.4, as appropriate. Hazard Division 6.1 requirements shall also be applied so that the explosives and toxic chemical hazards both are considered.

Table 3-5. Hazard Classifications/Compatibility Groups.

	Items	CG	DoD Q-D Hazard Division	Old DoT Class (Note 1)
1.	Initiating Explosives	A	1	A
2.	Detonators and similar initiating devices	B	1, 2, or 4	A or C
3.	Bulk propellants, propelling charges, and devices containing propellant with or without means of initiation	C	1, 2, 3, or 4	A, B, or C
4.	EIDS, black powder, high explosives, and HE ammunition without its own means of initiation and without a propelling charge	D	1, 2, or 5	A
5.	HE ammunition with its own means of initiation, with a propelling charge	E	1 or 2	A
6.	HE ammunition with its own means of initiation with or without a propelling charge	F	1 or 2	A
7.	Fireworks and illuminating, incendiary, smoke, or tear producing ammunition other than ammunition that is activated by exposure to water or the atmosphere	G	1, 2, 3, or 4	A, B, or C
8.	Ammunition containing both explosives and white phosphorus or other pyrophoric material	H	2 or 3	A or B
9.	Ammunition containing both explosives and flammable liquid or gel filler	J	3	B
10.	Ammunition containing both explosives and toxic chemical agent	K	2	A
11.	Ammunition not included in other groups, requiring separate storage	L	1, 2, 3, or 4	A, B, or C
12.	Ammunition containing only EIDS	N	6	
13.	Ammunition that presents no significant hazards	S	4 or none	C or exempt

Note 1 See 49 CFR 173 (reference (c)), 1992 version.

Table 3-6. EIDS and EIDS Ammunition Hazard Divisions.

EIDS and EIDS Ammunition	Hazard Classification
EIDS bulk	1.5D
EIDS Loaded projectiles and/or warheads w/o fuzes or with EIDS fuzes[1, 2]	1.6N
EIDS fuzes[1]	1.4D, 1.4S, 1.6N
EIDS loaded projectiles and/or warheads w/1.3 propelling charges and without fuzes or with EIDS fuzes[1, 2]	1.2C, 1.3C, 1.4C
EIDS loaded projectiles and/or warheads with non-EIDS fuzes and without 1.3 propelling charges	1.2D[3, 4], 1.4D[4]
EIDS loaded projectiles and/or warheads with non-EIDS[2,4] fuzes and with 1.3 propelling charges	1.2E[3, 4], 1.4E[4]

Notes:

1 "EIDS Fuzed" means that the fuze has an EIDS booster with an out-of-line EIDS explosive and two or more independent safety features. The fuze must be certified as invulnerable to accidental detonation of the warhead.

2 Fuzed configuration must be tested for propagation. Fuzed Hazard Division 1.6 ammunition must contain either an EIDS fuze or a non-explosive fuze (fuze contains no explosive); otherwise the ammunition is classified as unit risk Hazard Division 1.2.

3 Unit risk Hazard Division 1.2 may be justified on a case-by-case basis.

4 Fuze must have two or more independent safety features and independently classified Group D.

CHAPTER 4

PERSONNEL PROTECTION

A. Scope and application

This Chapter establishes blast, fragment, and thermal hazards protection principles and applies to all operations and operational facilities where personnel are exposed to ammunition and explosives hazards during industrial, processing, manufacturing, maintenance, renovation, demilitarization and similar operations. Structures to Resist the Effects of Accidental Explosions (TM 5-1300, NAVFAC P-397, AFM 88-22 (reference (g))) details design procedures to achieve personnel protection as required by this Chapter; protect facilities and equipment from damage by blast, fragments, and debris; and prevent propagation of explosions.

B. Hazard assessment

1. Assessment of risk shall be performed on all new or modified industrial operations and facilities involving ammunition and explosives. Based upon this assessment, engineering design criteria for the facility or operation shall be developed for use in the selection of appropriate equipment, shielding, engineering controls, and protective clothing for personnel. The assessment shall include such factors as:

a. Initiation sensitivity.

b. Quantity of materials.

c. Heat output.

d. Rate of burning.

e. Potential ignition and initiation sources.

f. Protection capabilities of shields, various types of clothing, and fire protection systems.

g. Personnel exposure with special consideration.

2. New or modified buildings sited within any explosives inhabited building Q-D arc that have glass panels and that contain personnel shall receive a glass breakage personnel hazard risk assessment.

C. Permissible exposures

1. Accidental ignition/initiation of explosives

a. Personnel shall be provided protection from potential blast overpressures, hazardous fragments, and thermal effects with attendant respiratory and circulatory hazards, when assessments performed in compliance with section B., above, indicate the probability of an accidental explosion with attendant overpressures, and hazardous fragments, or an accidental flash fire with attendant thermal hazards is above an acceptable risk level as determined on a case-by-case basis by the DoD Component concerned.

b. When required by paragraph C.1.a., above, protection afforded all personnel must be capable of limiting incident blast overpressure to 2.3 psi, fragments to energies of less than 58 ft-lb, and thermal fluxes to 0.3 calories per square centimeter per second. Those protection levels shall be certified through analysis for cases where personnel are at distances less than K24 or for situations where personnel exposure criteria are obviously exceeded. Shields complying with MIL-STD-398 (reference (h)) are acceptable protection.

2. **Intentional ignition/initiation of explosives**. At operations where intentional ignition/initiation of explosives are conducted, such as function, proof, lot acceptance, testing, and so forth, and where shielding is required as determined on a case-by-case basis by the DoD Component concerned, protection afforded all personnel will meet the requirements of paragraph C.1.b, above, and must also be capable of limiting overpressure levels in personnel-occupied areas to satisfy MIL-STD-1474C (reference (i)), containing all fragments, and limiting thermal flux to:

$$Q \text{ (calories/square centimeter/second)} = 0.62t^{-0.7423}$$

where t is the time in seconds that a person is exposed to the radiant heat. Shields complying with MIL-STD-398 (reference (h)) are acceptable protection.

D. Protective measures

Personnel protection requirements of section C., above, may be achieved in one or more of the following ways:

1. Elimination or positive control of ignition and initiation stimuli.

2. Sufficient distance or barricades to protect from blast or fragments.

3. In those areas of facilities where exposed thermally energetic materials are handled that have a high probability of ignition and a large thermal output as indicated by hazard assessments performed in compliance with section B., above, a fire detection and extinguishing system that is sufficiently quick-acting and of adequate capacity to extinguish potential flash fires in their incipient state will protect both personnel and property. Design and installation of the system must maximize speed of detection and application of the extinguishing agent.

4. In ammunition operational areas where it is essential for personnel to be present, and the hazard assessment indicates that an in-process thermal hazard exists, use of thermal shielding between the thermal source and personnel is an acceptable means of protection. If shields are used, they shall comply with MIL-STD-398 (reference (h)). If shielding is not possible, or if that provided is inadequate for protection of exposed personnel, including their respiratory and circulatory systems, augmentation with improved facility engineering design, personnel protective clothing and equipment may be necessary.

5. Thermal protective clothing must be capable of limiting bodily injury to first degree burns (0.3 calories per square centimeter per second with personnel taking turning-evasive action) when the maximum quantity of combustible material used in the operation is ignited.

6. Protective clothing selected must be capable of providing respiratory protection from the inhalation of hot vapors and toxicological effects when the hazard assessment indicates adverse effects would be encountered from the inhalation of combustion products.

7. Personnel hazards from glass breakage can be minimized by means such as building orientation and/or keeping the number of exposed glass panels and panel size to a minimum. When window panels are necessary and risk assessment determines a glass hazard will be present, blast resistant windows must be used. The framing and/or sash of such panels must be of sufficient strength to retain the panel in the structure.

CHAPTER 5

FACILITIES CONSTRUCTION AND SITING

A. General

Construction features and location are important safety considerations in planning facilities that are to be a PES or exposed to the damaging effects of potential explosions; i.e., an ES. The effects of potential explosions may be altered significantly by construction features that limit the amount of explosives involved, attenuate resultant blast overpressure or thermal radiation, and reduce the quantity and range of hazardous fragments and debris. Proper location of exposed sites in relations to PESs ensures against unacceptable damage and injuries in the event of an incident. This Chapter contains siting and construction standards to be used within the Department of Defense.

B. Ammunition and explosives storage facilities

1. **Earth-covered magazines (ECM).** The primary objective of an earth-covered magazine is to provide protection for its assets. To qualify for the default intermagazine distances in Table 9-5, a magazine, acting as an ES, must not collapse. Substantial plastic deformation of the magazine may occur. However, deflections should be limited within the air gap around the stored assets so that the deformed structure or its doors(s) do not strike the contents. Due to their extreme sensitivities, special protective precautions must be taken for compatibility group (CG) B explosive materials.

a. Default intermagazine siting criteria for ECMs are listed in Table 9-5. Magazines with headwall and blast door hardnesses of "7-Bar", "3-Bar" and "Undefined" are shown. All ECMs in Table 9-5 have the same earth cover requirements.

(1) **Design load for rear walls, arches, and roofs**

(a) The arch of an arch-shaped magazine need only be designed to support the conventional dead loads.

(b) The roof of a flat-roofed magazine must be designed for both dead loads and dynamic, blast-induced loads.

(c) The rear wall of a magazine must be designed for both dead loads and dynamic, blast-induced loads.

(2) **Design load for head walls and doors**

(a) The expected blast load on the head wall and doors of an ES magazine oriented side-on to the side of a PES at a 1.25 $W^{1/3}$ distance (feet) is a triangular pulse of 3 bars (45 psi) with a duration of about 0.768 $W^{1/3}$ (ms).

(b) The expected blast load on the head wall and doors of an ES magazine oriented head-on to the rear of a PES at a 2 $W^{1/3}$ distance (feet) is a triangular pulse of 7 bars (100 psi) with a duration of about 0.768 $W^{1/3}$ (ms).

b. ECMs in the following list, or ECMs that have equivalent hardness to those in the list, may be sited as 7-Bar ECMs for NEWs up to 500,000 pounds in accordance with Table 9-5.

(1) Reinforced concrete, arch-type, ECMs whose construction is at least equivalent in strength to the requirements of The Office of Chief of Engineers (OCE), Department of the Army, drawings 652-686 through 652-693, December 27, 1941, as revised March 14, 1942, 33-15-06, Europe Dist. 33-15-16, 33-15-58 (atomic blast resistant), 33-15-61, and 33-15-74. For new construction use drawings 33-15-74.

(2) Magazines constructed according to Navy drawings 357428 through 357430, August 9, 1944, and modified in accordance with NAVFAC drawing 626739, March 19, 1954; and NAVFAC drawings 627954 through 627957, 764597, 658384 through 658388, 724368, 751861, 764596, 793746, and 793747. For new construction use NAVFAC drawings 1404310 through 1404324, September 12, 1983.

(3) Box-type A magazines constructed according to NAVFAC drawings 1404000 through 1404007; box-type B magazines constructed according to NAVFAC drawings 1404018 through 1404025.

(4) Earth-covered, corrugated steel, arch-type magazines at least equivalent in strength to those shown on Army OCE drawings numbered AW 33-15-63, March 5, 1963; AW 33-15-64, May 10, 1963; 33-15-65, January 10, 1963; and NAVFAC drawings numbered 1059128-30, 1059132, 1069906, and 1355460-61. OCE 33-15-73 (oval 1-ga steel arch) and NAVFAC drawings 1404026-1404034 (oval 1-ga steel arch) are no longer approved for new construction. However, existing magazines are considered as 7 Bar magazines. Magazines described in Air Force definitive drawings AS 33-15-67R2, AD 33-15-68R2, AD 33-15-69R2 and AD 33-15-70R1 (constructed in accordance with drawings AW 33-15-63 and AW 33-15-64) may be sited as 7 Bar magazines. For new construction of large magazines of this type use the earth-covered steel, semi-circular-arch magazine design shown on Army OCE drawing number 421-80-01, and for new construction of smaller magazines of this type use OCE drawing number 33-15-65.

(5) Earth-covered Circular Composite Arch Magazine described in NAVFAC drawing numbers 1404375 through 1404389, October 31, 1985, and the Earth-covered Oval Composite Arch Magazine described in NAVFAC drawing numbers 1404390 through 1404398, October 31, 1985.

c. NAVFAC box-type C, D, E and F ECMs, or ECMs that have equivalent hardness to those in the list, may be sited as 7-Bar ECMs for NEWs up to 350,000 pounds in accordance with Table 9-5.

d. ECMs whose headwalls and blast doors have hardnesses of 3-Bars may be sited in accordance with the appropriate columns in Table 9-5 for NEWs up to 500,000 pounds.

e. ECMs in the following list, or ECMs that have equivalent hardness to those in the list, may be sited as magazines of undefined hardness for NEWs up to 500,000 pounds in accordance with Table 9-5. Presently approved sitings for explosives weights not exceeding 250,000 pounds remain valid. Future sitings must reflect the appropriate criteria in Table 9-5.

(1) Any ECM of undefined or unknown strength.

(2) Magazines constructed in accordance with NAVFAC drawings 649602 through 649605, 793748 and 803060.

2. **Barricaded open storage modules**

a. As depicted in Figure 5-1, a module is a barricaded area comprised of a series of connected cells with hard surface storage pads separated from each other by barricades. A light metal shed or other lightweight fire retardant cover may be used for weather protection for individual cells. Heavy structures (reinforced concrete, dense masonry units) or flammable material will not be used.

b. Module storage (open storage) is a temporary expedient and may be used as determined necessary by the DoD Component concerned. However, from the standpoint of explosives safety as well as reliability, priority shall be given to covered storage (igloos) for items requiring protection from the elements or long-term storage.

c. The maximum NEW permitted to be stored within each cell is 250,000 lbs (total of the explosives fill of all Hazard Division 1.1 or 1.2 ammunition).

d. **Authorized storage**

(1) The items that may be stored in modules are limited to HE bombs (fuzed or unfuzed, with or without fins), similarly cased Hazard Division 1.1 ammunition, and the following contained in nonflammable or metal shipping containers: 30 mm and smaller ammunition, CBUs, inert munitions components, and Hazard Division 1.4 munitions.

(2) Stocks in each module normally shall be limited to one type of item in the standard shipping configuration unless mixed storage is authorized by the DoD Component concerned.

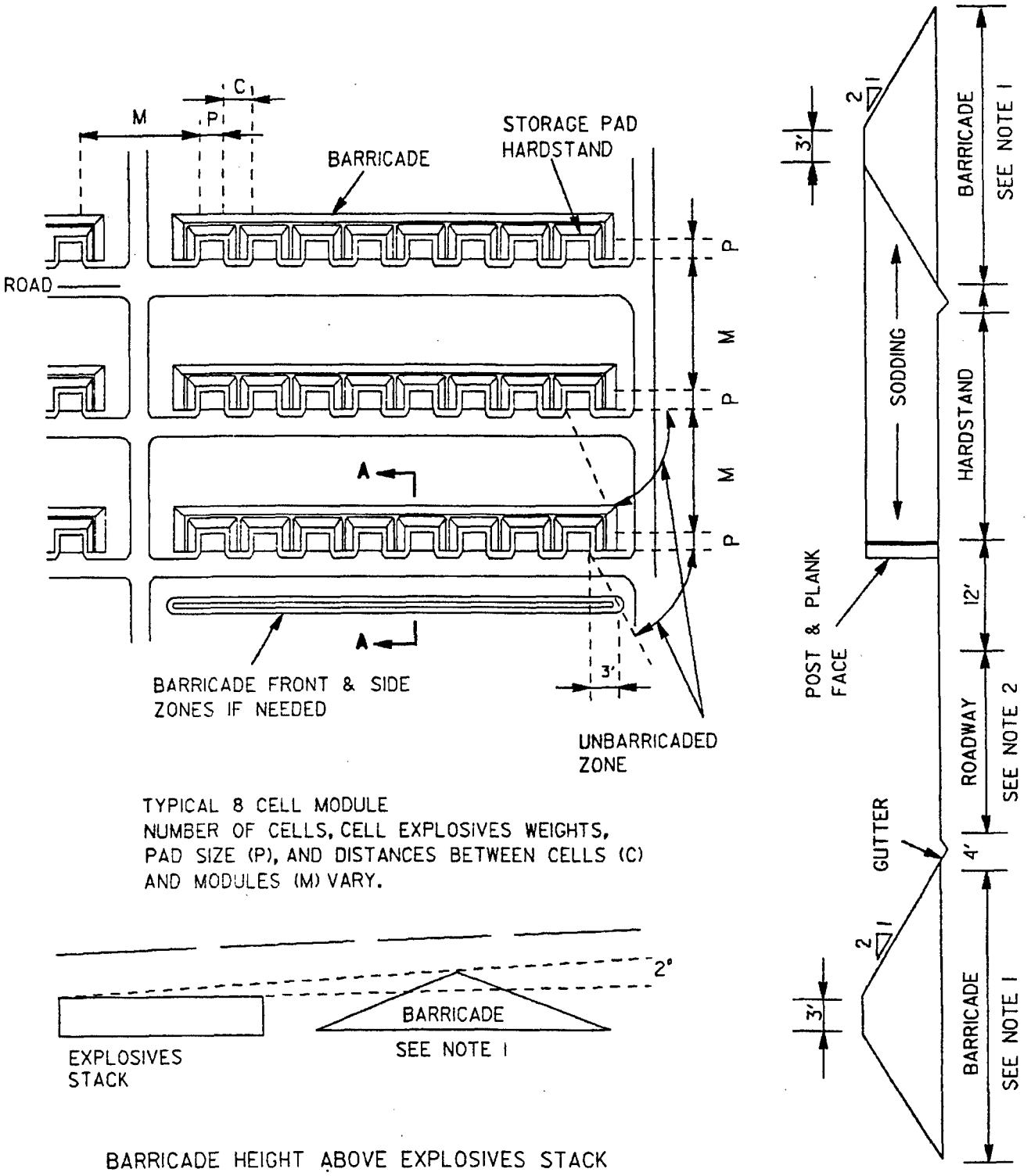
(3) Module storage of ammunition in flammable outer-pack configurations shall be minimized. Combustible dunnage or other flammable material shall not be stored in or within 100 feet of modules.

(4) When fire retardant tarpaulins are used to cover ammunition in modules, ventilation shall be provided between the tarpaulin and the stored ammunition.

e. **Barricade requirements**

(1) All barricades used in forming the module and its cells shall meet the requirements specified in section C., below. Minimum barricade height required above the top of the stack is influenced by the width or length of the stack (storage pad size) and the distance between the stack and the top of the barricade. Heights in Table 5-1 represent the minimum requirement for barricade locations based upon storage pad sizes and separations shown. When feasible, barricade heights shall be increased by using a 5° angle above the horizontal instead of the 2° shown in Figure 5-1. Reference paragraph C.2.c., below.

(2) The centerlines of barricades between cells of the module shall be located at a point halfway between adjacent munitions storage pads. Back and end (outside) barricades shall be located at the same distance from the pads as those between the cells.



NOTE:

1. REFER TO PARAGRAPH C2e FOR ALTERNATE BARRICADE TYPES
2. TO BE DETERMINED BY THE INSTALLATION.

Figure 5-1. Typical Eight-cell Module

Table 5-1. Intermagazine Separation for Barricaded Storage Module for Mass-Detonating Explosives.

Net Pounds of Explosives	Minimum Explosives-to-Explosives Distance in Feet (Barricaded) Between Cells & Modules $D = 1.1W^{1/3}$	Barricaded Height Based Upon Storage Pad Size	
		Cell Storage Pad Size (Width or Depth) in ft.[1]	Minimum Height Above Top of Stack in ft.
Column 1	Column 2	Column 3	Column 4
50,000	40	30	2
100,000	50	30	2
125,000	55	30	2
150,000	60	30	2
175,000	60	30	2
200,000	65	30	2
200,000	65	40	2 1/2
225,000	65	40	2 1/2
250,000	70	40	2 1/2
250,000	70	50	3

Note 1 The barricade height above the explosives stack shown in Column 4 will be increased 6 inches for each 10 ft increase in width or depth of the pad size shown in Column 3.

(3) Maximum advantage shall be taken of natural barriers existing in the topography in siting these modules. If natural barriers are used to substitute for a portion of the module barricade, the protection provided shall be at least equivalent to that of the barricade.

f. Cell storage pad size may be as required to accommodate stocks. Table 5-1 gives minimum pad sizes necessary to handle most items in the explosives quantities given. Storage pads shall be hard-surfaced, if possible, in order to lessen the effects of earth shock from an accidental explosion. No restrictions are imposed upon the arrangement of cells within a module or upon the arrangements of groups of modules, except that cell openings may not face toward each other unless they are barricaded or meet the standard Q-D criteria for unbarricaded aboveground magazines.

g. **Siting criteria**

(1) **Separation between cells and modules.** Distance between the nearest edges of stacks of munitions in adjacent cells and modules shall be as shown for appropriate explosives weights in Table 5-1. When cell explosives loadings are established for weights other than those shown, minimum distances between stacks shall be determined by the formula distance = 1.1 times the cube root of the NEW in pounds ($D = 1.1W^{1/3}$).

(2) **Separation between modules and all other targets**

(a) Distance between a module and other magazines shall be determined by applying the intermagazine distances specified in Table 9-5.

(b) Distances between the explosives in the cells of a module and all other targets shall be determined upon the basis of the NEW of single cells. Distances shall be measured

between the nearest edge of the munitions stack in the "controlling" cell and the nearest point of the target concerned (see subsection B.2. of Chapter 9).

3. **Underground magazines.** No specific limitation on NEW applies to these facilities or to individual chambers within facilities. Explosives limits will be based upon equations or table values in section G., Chapter 9.

4. **Other magazines.** Existing magazines described by definitive drawings and specifically approved for the purpose by DoD Components are approved for storage of ammunition and explosives. Prior DDESB safety review and approval (section F., below) are required for new types of ammunition and explosives storage facilities and for existing facilities first being proposed for use in storing ammunition and explosives.

5. **Magazine siting requirements.** Magazines are sited relative to each other (that is, intermagazine distance) so that communication of explosion from one to another is unlikely. Actual siting requirements are influenced both by the construction features of the magazines and the types and quantities of ammunition and explosives they contain.

a. If the specified thickness and slope of earth on magazines, as described in section C, Chapter 2, are not maintained, the magazine will be sited as an Unbarricaded, Aboveground Magazine.

b. Magazines must not be structurally weakened such that their asset protection capability is reduced.

c. The DoD Component performing a siting or analysis is to determine if the construction of a magazine being sited is equivalent to the requirements indicated on applicable drawings.

d. New construction of earth-covered magazines must meet the minimum requirements of the current revisions of the drawings listed in pargraphs B.1.b. and B.1.c., above.

C. Barricades and earth cover for magazines

1. General

a. Properly constructed barricades or undisturbed natural earth are effective means for protecting ammunition or explosives, structures, or operations against high-velocity, low-angle fragments although the barricades may be destroyed in the process. Since such fragments move along ballistic trajectories rather than straight lines, reasonable margins in barricade height and length must be provided beyond the minimum dimensions that block lines of sight. Barricades also provide limited protection against blast in the immediate vicinity. They do not provide any protection against high-angle fragments and are ineffective in reducing the blast pressure in the far field (inhabited building or public traffic route distances).

b. Underground storage facilities present special conditions that must be accounted for in portal barricade design. Specific criteria for location and construction of portal barricades for these facilities are found in subsection C.5., below

2. **Barricade requirements for other than underground facilities.** Protection is considered effective when barricades meet the following minimum requirements:

a. The slope of a barricade may not be steeper than 1 1/2 horizontal to 1 vertical to meet explosives safety requirements. Facilities constructed in the future should have a slope of 2 horizontal to 1 vertical to reduce erosion and facilitate maintenance operations.

b. Earth barricades shall be made of material as indicated in subsection C.4., below.

c. Determine the height and length of barricades as follows:

(1) **Height**. Establish a reference point at the top of the far edge of one of the two stacks under consideration between which the barricade is to be constructed. This reference point, if the top of the stacks are not at the same elevation, shall be on the stack whose top is at the lower elevation. Draw a line from the reference point to the highest point of the other stack. Draw a second line from the reference point forming an angle of 2 degrees above the line. To preclude building excessively high barricades, the barricade should be located as close as possible to the stack on which the reference point was established. When the stacks are of equal height, the reference point may be established on either stack. See Figure 5-2.

(2) **Length**. The length of the barricade shall be determined as shown in Figure 5-3.

d. Earth barricades that meet the above requirements may be modified by substituting a retaining wall, preferably of concrete, for the slope on one side. The remaining side shall be of such slope and thickness as necessary to ensure that the width of earth required for the top is held firmly in place.

e. Other intervening barriers meeting the above requirements or proven effective by test also may be used, for example, earth-filled steel bin barricades for explosives-loaded aircraft. Barricades meeting the above requirements may be found in Army drawing 149-30-01.

3. **Location of barricades**

a. The distance between the foot of the barricade and the stack of ammunition or explosives or buildings containing explosives is necessarily a compromise. The smaller the distance, the less the height and length of the barricade required to secure proper geometry for intercepting projections. On the other hand, it may be essential to make the distance great enough to provide access for maintenance and vehicles.

b. If it is impracticable to locate the barricades as stated in paragraph C.3.a., above, barricades may be located adjacent to the facility to be protected.

4. **Earth cover for magazines and barricades**

a. Material for earth cover over magazines and for barricades shall be reasonably cohesive (solid or wet clay or similar types of soil may not be used as they are too cohesive), free from deleterious organic matter, trash, debris, and stones heavier than 10 pounds or larger than 6 inches in diameter. The larger stones shall be limited to the lower center of fills and will not be used for earth cover over magazines. Compaction and surface preparation shall be provided, as necessary, to maintain structural integrity and avoid erosion. When it is impossible to use a cohesive material, for example, in sandy soil, the barricade or the earth cover over magazines shall be finished with a suitable material to ensure structural integrity.

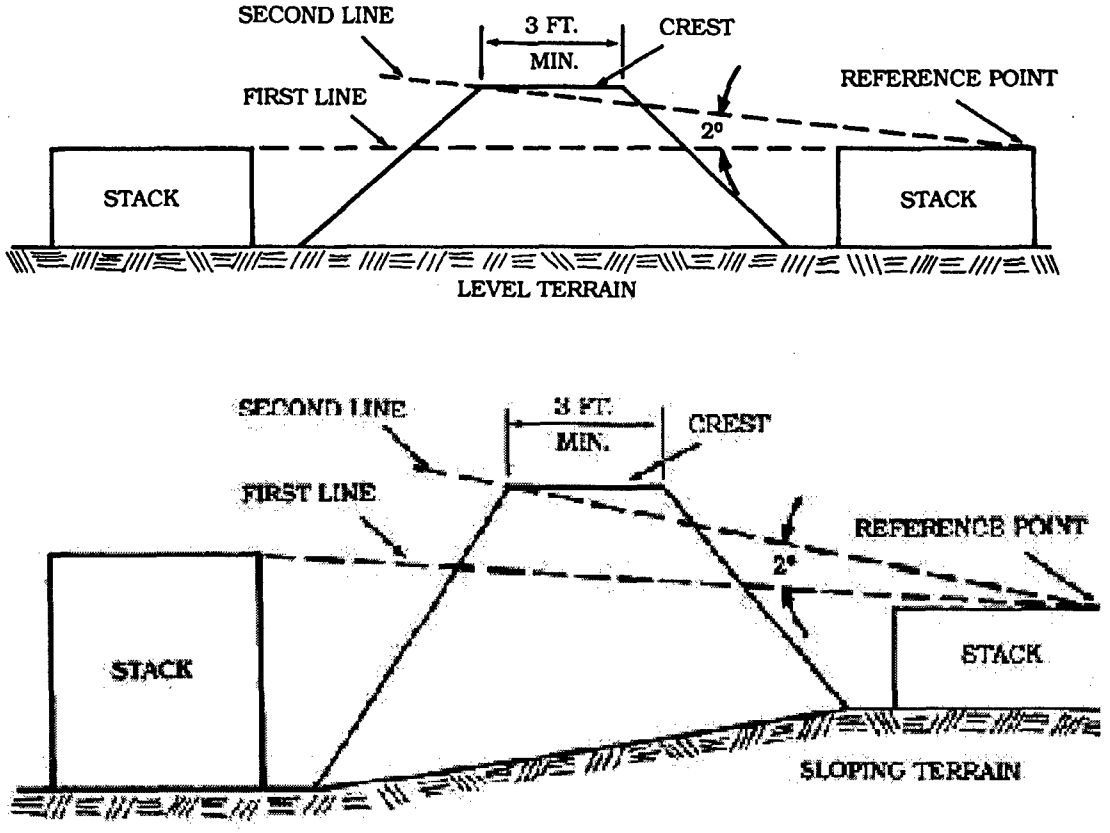


Figure 5-2. Determination of Baricade Height

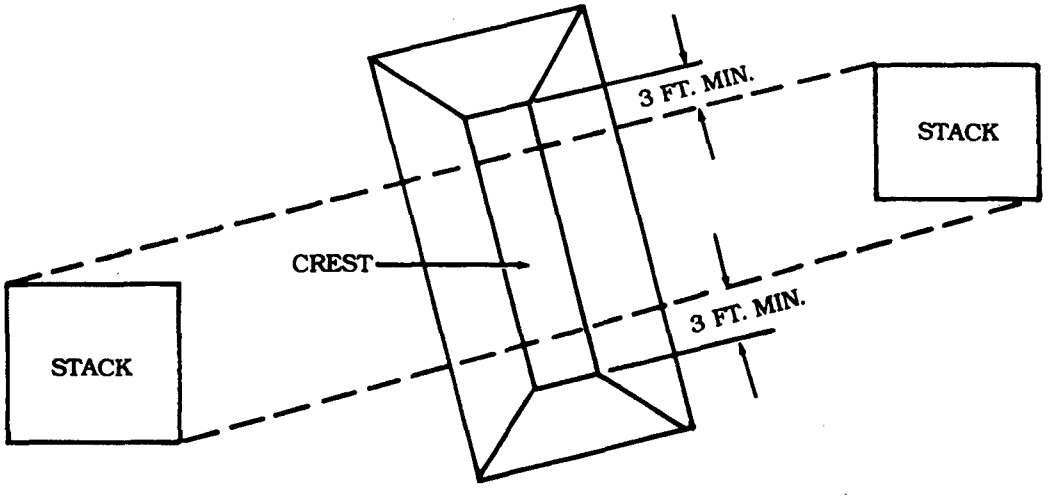


Figure 5-3. Determination of Barricade Length

b. The earth fill or earth cover between igloo magazines may be either solid or sloped in accordance with the requirements of other construction features, but a minimum of 2 feet or earth cover shall be maintained over the top of each magazine and a minimum slope of 1 1/2 horizontal to 1 vertical starting directly above the spring line of each arch shall be maintained to meet explosives safety requirements. Facilities constructed in the future shall have a slope of 2 horizontal to 1 vertical to reduce erosion and ease maintenance operations.

5. **Portal barricades for underground magazines**

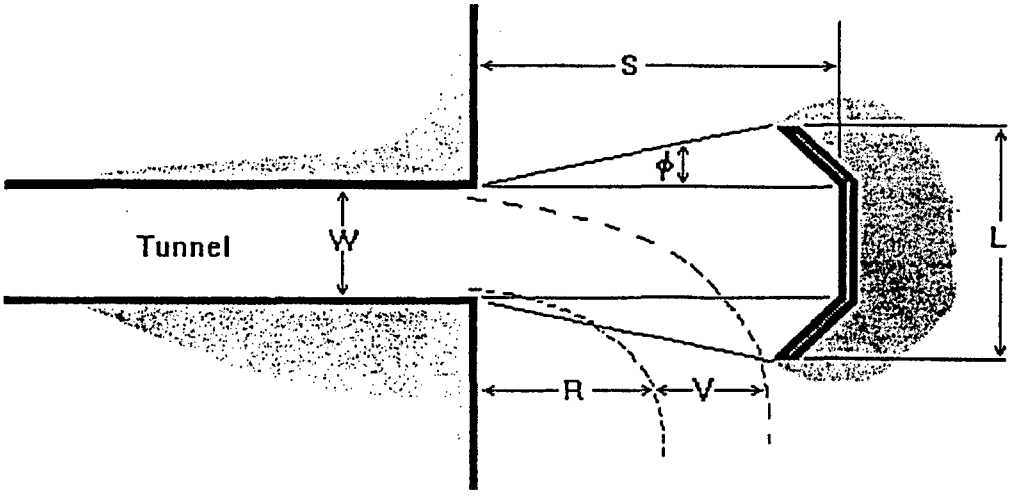
a. Portal barricades for underground magazines are located immediately in front of an outside entrance or exit (that is, the portal) to a tunnel leading to an explosives storage point. The portal barricade should be centered on the extended axis of the tunnel that passes through the portal. Specific design criteria for a portal barricade are given in the Corps of Engineers definitive drawing number DEF 421-80-04. The remaining narrative of this paragraph is given for conceptual guidance. For maximum effectiveness, the front face (that is, the face toward the portal) of the barricade must be vertical and concave in plan, consisting of a central face oriented perpendicular to the tunnel axis, and wingwalls as shown in Figure 5-4. The width of the central face typically equals the width of the tunnel at the portal. The wingwalls must be of sufficient width so that the entire barricade length intercepts an angle of ten degrees (minimum) to the right and left of the extended tunnel width. Likewise, the height of the barricade along its entire width must be sufficient to intercept an angle of ten degrees above the extended height of the tunnel.

b. Portal barricades for underground magazines must be located a distance of not less than one and not more than three tunnel widths from the portal. The actual distance should be no greater than that required to allow passage of any vehicles or materials handling equipment that may need to enter the tunnel. As shown in Figure 5-4, this distance is based on the turning radius and operating width required for the vehicles or equipment.

c. To withstand the impact of debris ejected from the tunnel; the front face of the portal barricade (including wingwalls) must be constructed as a wall of reinforced concrete, with a minimum thickness equal to 10 percent of the barricade height, but in no case less than 12 inches. The concrete wall must have a spread footing of sufficient width to prevent significant settlement, and the central wall, wingwalls, and footing must be structurally tied together to provide stability. The backfill behind the concrete wall may be composed of any fill material, including rock rubble from the tunnel excavation, with a maximum particle size of six inches within the area extending out to three feet from the rear face of the wall.

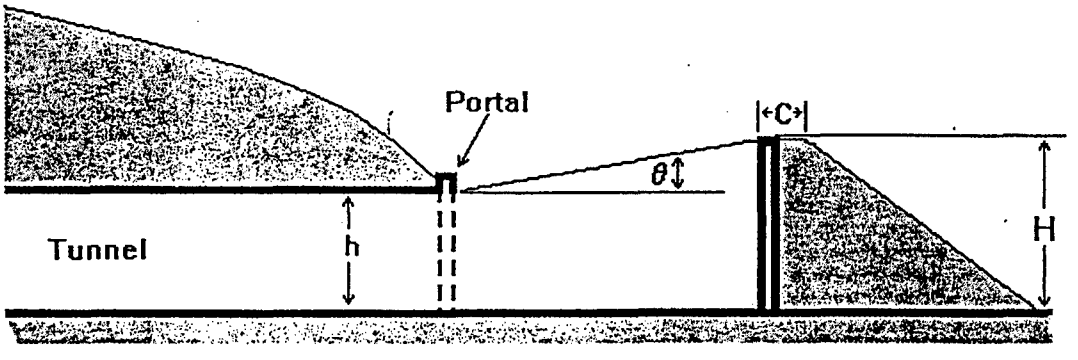
6. **Earth-filled, steel bin-type barricades (Armco Inc. revetments or equivalent) for outside storage**

a. These barricades, also known as Armco Inc. revetments, are earth-filled steel bins used to separate munitions awaiting scheduled processing, for example, munitions on flight lines associated with aircraft parking/loading operations or the temporary positioning of munitions awaiting transfer to preferred, long-term storage. The barricades are also used to separate uploaded aircraft. These barricades are normally used to form a series of cells. The barricades are designed to limit the MCE (for Q-D siting purpose) of the munitions stored in separate cells by preventing prompt detonation transfer to adjacent cells provided the munitions in each cell of the facility are properly positioned.



a. Plan View

S = Stand-off distance from portal (1 to 3 tunnel widths)
R = Turning radius of munition transport vehicles
V = Width of transport vehicles
L = Length of barricade
W = Tunnel width at portal
ϕ = Side angle [10 degrees minimum]



b. Elevation View

C = Crest Width [See DEF 421-80-04]
H = Height of barricade
h = Height of tunnel
θ = Elevation angle [10 degrees minimum]

Figure 5-4. Portal Barricade Location, Height and Length.

b. It is important to recognize that Armco Inc. revetment cells have been evaluated for a limited number of munitions. The DDESB Secretariat will maintain and distribute a current list of all Service munitions qualified for storage in Armco Inc. revetments cells.

c. Armco Inc. revetments as sited in paragraph C.6.d., below, should only be considered for preventing prompt detonation transfer, and that all munitions (and aircraft) in the series of cells are at risk of loss. In other words, although the revetments are effective in limiting the blast loading of adjacent ESs to that produced by the largest contents of a single cell, there is a significant probability that the contents of many cells will be damaged or destroyed by the initial and subsequent fire and explosion events. The extent of such losses increases with the amount of explosives present. Therefore, if valuable munitions and/or aircraft assets are to be preserved, then the quantities allowed in cells should be limited to satisfy valid essential operational requirements.

d. There are two types of Armco Inc. revetments, Type A and Type B. Type A revetments must be a minimum of seven feet thick. Type B revetments must be a minimum of 5.25 feet thick. Type A Armco Inc. revetments may be used to limit the MCE in a series of cells to the largest quantity in a single cell if that quantity does not exceed 30,000 pounds NEW. Type B Armco Inc. revetments may similarly be used to limit the MCE, provided no cell contains more than 5,000 pounds NEW. The following conditions must be met.

(1) In addition to satisfying the criteria illustrated in Figures 5-2 and 5-3, munitions must be positioned no closer than ten feet from cell walls, no closer that three feet from the end of the wingwalls, and no higher than two feet below the top of cell walls.

(2) Munitions shall be positioned with the objective of distributing them over the available area within the cell, rather than concentrating them in the small area. The contents of a cell (stored in quantities near the maximum NEW limit) must not be configured into a single row of pallets, stacks, or trailers.

(3) Storage of munitions in inflammable outer-pack configurations must be minimized.

D. Policy on protective construction

Advances in protective construction permit achievement of any calculated level of protection from explosion communication between adjacent bays or buildings, for personnel against death or serious injury from incidents in adjacent bays or buildings, and for vital and expensive equipment installations. Therefore, the major objectives in facility planning shall be:

1. Provision of protection against explosion communication between adjacent bays or buildings and protection of personnel against death or serious injury from incidents in adjacent bays or buildings (see subsection B.2. of Chapter 9). When the protection of personnel and facilities would be greatly enhanced or costs reduced significantly by having separate buildings to limit explosion propagation rather than using protective construction and separation of explosive units within one building, planning shall reflect this fact.

2. Provision for protection of vital and expensive equipment, if the additional cost is warranted.

3. When an appropriate degree of protection can be provided either by hardening a target building or construction of a source building to suppress explosion effects, these factors may be taken into account and the distance required by the standard Q-D tables may be reduced. Site and general construction plans for ammunition and explosives facilities that propose reduced distances based upon protective construction shall be accompanied by the rationale or test results that justify the reduction when they are submitted for DDESB approval (see section F., below).

E. Facilities siting criteria

This section establishes criteria for siting explosives and nonexplosives facilities with respect to PESs.

1. Administration, industrial, and convenience areas

a. Administration and industrial areas shall be separated from PESs by inhabited building distances.

b. Auxiliary facilities such as heating plants, line offices, break areas, briefing rooms for daily work schedules or site safety matters, joiner shops, security posts, and similar functions located at or near explosives operations and servicing only one building or operation shall be so located and constructed as to provide fire protection (See paragraph D.1.g. of Chapter 2).

2. Classification yard

a. For protection of the classification yard from external explosions, separation distances shall be at least the applicable magazine distance.

b. Specific Q-D separation is not required from the classification yard to targets other than explosives locations when the classification yard is used exclusively for:

(1) Receiving, dispatching, classifying, and switching of cars.

(2) Interchanging of trucks, trailers, or railcars between the common carrier and the DoD activity.

(3) Conducting external inspection of motor vehicles or railcars, or opening of free rolling doors of railcars for the purpose of removing documents and making a visual inspection of the cargo.

c. If the yard is used at any time for any purpose other than listed in paragraph E.2.b., above, such as placing or removal of dunnage or explosives items into or from railcars, Q-D tables apply.

3. **Areas for burning ammunition and explosives**. Use the Q-D formula described in paragraph B.2.a., Chapter 9 and the requirements in paragraphs E.3.a. through E.3.c., below, to determine safe locations for burning ammunition and explosives.

a. Use a risk factor of K24 in the Q-D formula to determine the minimum safe distance for either personnel burning ammunition and explosives and/or those conducting unrelated ammunition operations.

b. Use a risk factor of K40 in the Q-D formula to determine the safe distance for persons not performing ammunition operations. However, if the NEW of burn material is more than 100

pounds, the minimum safe distance shall be at least 1,250 feet. The minimum safe distance for a NEW of 100 pounds or less shall be at least 670 feet.

c. Locate burning grounds at intraline distance from other PESs.

4. **Ranges used for destruction of ammunition, demonstrations, and explosive ordnance disposal (EOD)**

a. The minimum separation distances between ranges (where explosives demolitions, demonstrations, and EOD explosives operations are conducted) and non-essential personnel are determined by application of the criteria given below. If the minimum separation distance requirements for previously approved DDESB sitings or those prescribed in this section cannot be met, then personnel shall be provided with protection as specified in subsection C.2., Chapter 4.

(1) Distance (Feet) = 328 $W^{1/3}$, but not less than 1250 feet, for non-fragmenting explosive materials. If known, maximum debris throw ranges, with an applicable safety factor, may be used to replace the 1250 feet minimum range.

(2) Distance (Feet) = 328 $W^{1/3}$, but not less than 2500 feet, for fragmenting explosive materials. For bombs and projectiles with caliber 5 inches or greater use a minimum distance of 4000 feet. The maximum fragment throw range (including the interaction effects for stacks of items or single items, whichever applies), with an appropriate safety factor, may be used to replace the 2500 feet or 4000 feet minimum ranges. Items should be sited so that lugs and/or strongbacks and nose and/or tail plate sections are oriented away from personnel locations.

b. **Separation distances for EOD operations**

(1) EOD operational incidents involving threat devices require the application of public withdrawal distances to all non-essential personnel as prescribed in Table 8-2.

(2) EOD operations and/or demonstrations conducted on ranges require minimum non-essential personnel separation distances defined in paragraph E.4.a., above.

(3) Essential personnel conducting EOD training operations, or operations involving demolition of explosives and ammunition, do not require minimum separation distances. Protection of these individuals shall be determined by competent on-site authorities.

(4) EOD training ranges to maintain EOD proficiency are limited to a maximum of 5 lb of demolition explosives (bare charges or items without a fragment hazard). The ranges are to be constructed and sited as follows:

(a) The destruction point must be at least 500 feet from all other facilities, such as those with inhabited building, public traffic route, or intraline distance requirements.

(b) If the destruction point separation distance cannot satisfy the 500 feet requirement described above, then the separation distance may be reduced to 300 feet if the range is limited to 2.5 lb, or 200 feet if the range is limited to 1.25 lb of demolition explosives. Destruction points located with these reduced distances must be barricaded as follows:

1 A barricade is to be constructed within 10 feet of the destruction point to control ejection of debris. It must be the equivalent of two sandbags thick and at least six feet high.

2 The barricade must have two entrances opposing each other at 180 degrees separation. Each entrance must have a barricade equivalent to two sandbags thick and be long enough to effectively block all fragments and blast.

(c) If a training range is used for operations that will produce fragments above the level expected for normal EOD proficiency training (normally open shots), then the range must satisfy the requirements of paragraph E.4.a., above.

(d) The range distance may be reduced to 100 feet if the EOD training is done using explosively operated tool kits. In this case, the site must be barricaded as described above, and only inert ammunition items used for training.

c. Due to ballistic uncertainties for impact locations of various weapons and delivery systems, where demonstrations involve live fire exercises, range safety considerations shall be determined on a case-by-case basis by competent test authorities.

d. Protective structures for personnel or measures taken to suppress blast and/or fragment effects, at disposals and demonstrations, may be used to reduce the required withdrawal distance.

e. The minimum separation distances for essential personnel at disposal operations and demonstrations are to be determined by applicable authorities on site. These authorities shall also determine who are essential personnel.

f. Control sites for ammunition and explosives destruction, demonstration, and EOD operations must be at intraline distance from other PESs based on the PES NEW.

5. **Inert storage area**. The DoD Component concerned shall determine the acceptable protection for such areas after consideration of the value and importance of material in relation to the mission of the installation, the operational conditions, and the availability of space.

6. **Interchange yards**. Truck, trailer, or railcar interchange yards are not subject to Q-D regulations when they are used exclusively:

a. For the interchange of vehicles or railcars containing ammunition and explosives between the commercial carrier and DoD activities.

b. To conduct external inspection of the trucks, trailers, or railcars containing ammunition and explosives.

c. To conduct visual inspection of the external condition of the cargo in vehicles (such as trucks, trailers, and railcars) that passed the external inspection. If the yards are used at any time for any purpose other than above, applicable Q-D tables apply (see paragraph B.2.g., Chapter 9).

7. **Inter-service support and tactical facilities**. Application of Q-D standards between inter-Service support facilities and for inter-Service tactical facilities.

a. **General**

(1) Appropriate safety distances as provided in paragraph E.7.b., below, shall be applied between facilities of one Military Service to facilities of another Military Service regardless of the location of the boundary between the two Service installations.

(2) Safety criteria based on toxicity, noise, thermal radiation, flight trajectory, fragmentation, incendiary, or other hazards may be greater than explosives safety distance criteria, in which case the criteria based on the predominant hazard shall be considered.

b. The following Q-D relationships shall apply to the separation of facilities of two Services:

(1) Explosives storage facilities of one Military Service shall be separated from explosives storage facilities of another Military Service, as a minimum, by appropriate intermagazine distance.

(2) Explosives storage or operating locations of one Military Service shall be separated from explosives operating locations of another Service by appropriate inhabited building distance. When operations in each facility present a similar degree of hazard or for joint or support operations, this separation may be reduced to the appropriate intraline distance.

(3) Explosives storage or operating locations of one Military Service shall be separated from explosives tactical facilities of another Service by appropriate inhabited building distance. For joint or support operations, use the appropriate separation distance as though both facilities belonged to a single Military Service.

8. **Loading docks**. Detached loading docks which normally service multiple facilities shall be sited on the basis of use. When servicing magazines, they must be separated from the magazines by intermagazine distances. When servicing operating buildings, they must be separated from the operating buildings by intraline distances.

9. **Railcar and truck holding yards**

a. Generally, railcar holding yards shall be laid out on a unit railcar-group basis with each group separated by the applicable aboveground magazine distance.

b. If the railcar holding yard is formed by two parallel ladder tracks connected by diagonal spurs, the parallel tracks and the diagonal spurs shall be separated by applicable aboveground magazine distance for the unit-group quantities of HE.

c. If the railcar holding yard is a "Christmas tree" arrangement, consisting of a ladder track with diagonal dead-end spurs projecting from each side at alternate intervals, the spurs shall be separated by the applicable aboveground magazine distance for the net weight of high explosives in the railcars on the spurs.

d. Generally, truck holding yards shall be laid out on a unit truck-group basis with each group separated by the applicable aboveground magazine distances.

e. Both railcar and truck holding yards shall be separated from other facilities by the applicable IBD, PTR, ILD or IMD Q-D criteria.

f. In addition to the temporary parking of railcars, trucks, or trailers containing ammunition and explosives, holding yards may also be used to interchange truck, trailers or railcars between the commercial carrier and the DoD activity and to conduct visual inspections.

10. **Railcar and truck inspection stations**

a. Specific Q-D separations are not required for inspection stations; however, they should be as remote as practicable from hazardous or populated areas. Activities that may be performed at the inspection station after railcars or motor vehicles containing ammunition and explosives are received from the delivering carrier and before further routing within the installation are:

(1) External visual inspection of the railcars or motor vehicles.

(2) Visual inspection of the external condition of the cargo packaging in vehicles (such as trucks, trailers, and railcars) that have passed the external inspection indicated in subparagraph E.10.a.(1), above.

(3) Interchange of trucks, trailers, or railcars between the common carrier and the DoD activity.

b. If any activities other than the above are conducted at the inspection station, Q-D applies.

c. Any railcars or trucks suspected of being in a hazardous condition shall be isolated consistent with applicable Q-D separation for the hazard class and explosives quantity involved. This shall be accomplished first, before any other later action.

11. **Ammunition/explosives transportation mode change locations**. Movement and transfer of DoD-titled ammunition and explosives must be in compliance with national, international, and host country-specific transportation regulations. Q-D criteria apply to all transfer operations involving DoD-titled ammunition except for:

a. Roll-on/roll-off operations (not involving lifting); and,

b. Off-installation MILVAN/ISO container inter-/intramodal transfers (involving highway and rail modes only) where containers are not stored or other operations are performed.

12. **Recreational and training facilities**. Open areas between explosives storage and handling sites and between these sites and nonexplosives buildings and structures shall be controlled carefully regarding use for recreation or training facilities. As a general rule, the fragment hazard will be severe from the explosion site out to approximately the public traffic route distances. Accordingly, recreation and training facilities, where civilian employees, military and civilian dependents, or the public are in the open, shall be sited at not less than public traffic route distances and at or as near inhabited building distances as practicable. When structures, including bleachers, are included as part of these facilities, they shall be sited at not less than inhabited building distances.

13. **Storage tanks for hazardous materials**

a. Large permanent storage facilities are of primary concern when applying quantity-distance (Q-D) criteria to storage tanks. For installation of smaller tanks, it may be desirable to weigh the cost of distance/protective construction against the strategic value of the stored

material, the ease of replacement in the event of an accident, and the potential environmental impact. Reduced distances may be approved if these losses are accepted by the DoD Component, if the tanks are sited and if spill containment is provided so other exposures are not endangered.

b. Small quantities of POL and other hazardous materials used for operational purposes require no specific separation distance for explosives safety; however, operating procedures must be implemented to limit adverse environmental impacts in the event of an accidental explosion.

c. Unprotected, aboveground storage tanks shall be separated from other PESs at IBD per Table 9-1, as a minimum, and shall be diked.

d. Unprotected service tanks, which provide sole support to aboveground explosives storage and operating complexes, and are supplied by a pipe system designed to resist potential blast and fragments, may be sited at incremented K40/K50 inhabited building distance with a minimum distance of 400 feet, provided:

(1) A dike system, meeting the requirements in NFPA 30, (reference (j)) is provided; and,

(2) The Service accepts the possible loss of the tanks and any collateral damage that a fire might cause as a result of the tanks being punctured by fragments.

e. A service tank supporting a single PES shall be separated, at a minimum, from that PES at the appropriate NFPA fire protection distance. The distance from this service tank to any other PES will be the larger of the required distance between the PESs or the appropriate NFPA fire protection distance.

f. Distances less than those for unprotected tanks may be used when an aboveground storage tank is provided sufficient protection from blast and fragment hazards to prevent rupture or collapse.

g. Buried tanks and buried pipelines should be separated from aboveground buildings or stacks containing ammunition or explosives of Hazard Divisions 1.2, 1.3 and 1.4 by a minimum distance of 80 feet. The required separation distance for ammunition in Hazard Division 1.1 is K3 with a minimum of 80 feet.

h. It is not practical to specify Q-D criteria that cover all configurations involving tank storage and underground ammunition storage facilities. Each case must be assessed on a site specific basis to take account of crater, blast, ground shock, debris hazards and potential, adverse environmental impacts.

14. **Storage tanks for water**

a. Loss of tank is unacceptable: Q-D for unprotected aboveground storage tanks in this category shall meet the siting requirements of paragraph E.13.c., above. Buried tanks and associated components of like value shall meet the siting requirements of paragraph E.13.g., above.

b. Loss of tank is acceptable: Q-D criteria do not apply to storage tanks and associated components in this category.

15. **Underground tanks or pipelines for non-hazardous materials.** These should be separated from buildings or stacks containing ammunition and explosives of Hazard Divisions 1.2

through 1.4 by a minimum distance of 80 feet. The separation for Hazard Division 1.1 shall correspond to the formula $D = 3.0W^{1/3}$ with a minimum distance of 80 feet, unless the donor building is designed to contain the effects of an explosion.

16. **Wharf yard**. Separation of a wharf yard from the pier which it serves by a distance clearly sufficient to prevent immediate propagation of an explosion ($11W^{1/3}$) will be impracticable in many cases. In such cases, the wharf yard will be considered as part of the ship or barge unit and added to it for computation of the total amount of explosives for Q-D purposes. The outer limit of the wharf yard then shall be considered as the ship unit boundary for computing applicable Q-D requirements.

17. **Parking lots**. Parking lots for privately owned automobiles belonging to personnel employed at or stationed at multiple PESs shall be sited at intraline distance from each PES. When a parking lot supports a single PES, it may be separated at less than intraline only from its associated facility. A minimum distance of 100 feet is required to the associated facility to protect it from vehicle fires. Access for emergency vehicles must be provided. Parking lots for administrative areas shall be located at public traffic route distance from all PESs (minimum fragment distance shall apply).

18. **Helicopter landing areas**. Helicopter landing areas for loading and unloading ammunition within storage sites and quick reaction alert sites shall be considered aboveground magazines and may be sited at appropriate quantity distances based only upon explosives carried by the helicopter(s). Intermagazine distances shall apply to magazines and maintenance buildings subject to the following requirements:

a. Flight clearance criteria are met.

b. Landing and takeoff approaches shall not be over magazines.

c. Helicopter operations are to be limited to ammunition support of the magazines concerned. Carrying passengers is not permitted.

d. Safety precautions normal to other modes of transportation, are to be observed. Explosives operations shall not be conducted in the magazines or maintenance buildings located within inhabited building distance from the helicopter landing area during takeoff, landing, or loading and/or off-loading of the helicopter(s). Those maintenance buildings and magazines shall be closed.

19. **Temporary construction operations**. Construction personnel who must, on a temporary basis, be near PESs to perform their job shall be provided the maximum practicable protection from the effects of an explosion should one occur at a PES. The DoD Component concerned shall determine the minimum practicable distance from which such personnel will be separated from PESs and shall control operations at the PESs so that the chance of an explosion occurring is kept to a minimum. Documentation showing the rationale for control measures taken shall be maintained until operations have been completed and personnel have permanently vacated the work site.

F. Site and general construction plans review

1. In accordance with DoD Directive 6055.9 (reference (k)), site and general construction plans for ammunition and explosives facilities as well as plans for changes in utilization of facilities or mission changes that adversely affect the explosives Q-D requirements shall be submitted to the DDESB for review and approval. Plans shall be forwarded for:

a. New construction or major modifications of facilities for ammunition and explosives activities. Modifications or rehabilitation plans for existing facilities do not require submission to DDESB when the plans do not introduce additional hazards or do not increase the net explosives capacity or chemical agent hazard for which the facility was designed or sited.

b. Facilities for activities not involving ammunition or explosives that are in such proximity to ammunition and explosives as to be exposed to hazards or for which a reasonable doubt may exist regarding possible exposure to hazards.

c. Facilities for activities not involving ammunition and explosives that become exposed to blast, fire, or fragment hazards; or potential toxic chemical agent release due to change in installation mission or facilities usage. For example, an airfield restricted to DoD Component use only being changed to joint DoD and non-DoD use.

2. When the review of site and general construction plans is required, the DoD Component concerned shall:

a. Indicate specifically in the letter of transmittal its approval of the proposal, along with changes, modifications, or specific precautionary measures considered necessary.

b. Submit drawings of site plans at a scale of 1 inch equals not more than 400 feet. Drawings of a smaller scale than that specified may be necessary periodically to properly reflect certain distance and structure relationships within the area surrounding a given project. A reduction in scale in such instances is acceptable. When standard drawings (definitive) for a building or group of buildings exist that have been reviewed by the DDESB and declared acceptable, the definitive drawings are not required. In these cases, only a site plan is required noting the definitive drawings for each building or structure to be constructed.

c. Indicate distances between the facility to be constructed or modified and other installation facilities, the installation boundary, public railways, and public highways, including power transmission and utility lines.

d. Identify all other facilities including their occupancy and use within inhabited building distance of the facility to be constructed or modified.

e. Provide descriptions of hazardous materials or items to be in the new or modified facilities such as, bombs, rockets, artillery ammunition, chemical agents, nuclear weapons, liquid propellants, or other items requiring protective measures in accordance with this Standard. Include results of tests to determine blast, fragmentation, and thermal hazards.

f. Indicate quantities, classes, and divisions of ammunition, explosives, chemical agents, liquid and solid propellants, or other hazardous material proposed for the new or modified facility.

g. Provide anticipated personnel limits for the new or modified facility, including a breakdown by room or bay when appropriate.

h. Provide general details regarding dividing walls, vent walls, firewalls, roofs, operational shields, barricades, exits, types of floor finish, fire protection system installations, electrical systems and equipment, ventilation systems and equipment, hazardous waste disposal systems, lightning protection system, static grounding systems, process equipment, and auxiliary support structures as well as general materials of construction, unless approved drawings are being used.

i. Provide a brief summary of the design procedures used if engineered protection is used to reduce the Q-D. This summary shall include a statement of the design objectives in terms of protection categories (as defined in TM 5-1300, NAVFAC P-397, and AFM 88-22, (reference(g))) to be obtained, explosives quantities involved, design loads applied, material properties and structural behavior assumptions, references, and sources of methods used. Detailed calculations are not required provided the protective designs used to reduce Q-D have been approved by the DDESB. Design of explosion resistant facilities shall be accomplished by an organization or individual experienced in the field of structural dynamics using design procedures accepted by professionals in the field. An appropriate source of effects data and design methods for explosion resistance is TM 5-1300, NAVFAC P-397, AFM 88-22, (reference (g)).

j. Furnish information on the type and arrangement of explosives operations or chemical processing equipment.

k. Provide a topography map with appropriate contours when terrain features are considered to constitute natural barricading, or topography otherwise influences layout as in some chemical operations.

l. Provide, in addition to the above and when chemical agents are involved, information regarding personnel protective clothing and equipment, treatment of effluent and waste materials to ensure absence of chemical agents, adequacy of medical support, average wind speed and direction, other support facilities pertinent to chemical safety, warning and detection systems, and hazard analysis, as appropriate.

m. Explain any deviations from pertinent safety standards caused by local conditions.

3. The information in subsection F.2., above, shall be submitted as follows:

a. Preliminary site plan approval (paragraphs F.2.a. through F.2.g. and F.2.m., above).

b. Final safety review (paragraphs F.2.a. through F.2.m., above).

4. A copy of the complete site plan and the final safety submission, together with DDESB letter(s) of approval, must be retained as a permanent record at the installation of origin. This information may be subject to review during future DDESB surveys.

CHAPTER 6

ELECTRICAL STANDARDS

A. General

The National Electrical Code, published by the National Fire Protection Association as NFPA 70 (reference (l)), does not specifically address explosives; however, Article 500 of the Code, Hazardous (Classified) Locations, does establish standards for the design and installation of electrical equipment and wiring in atmospheres containing combustible dusts and flammable vapors and gasses that, in general, are comparably hazardous. Exceptions are extraordinarily hazardous explosives, such as nitroglycerin, that require special consideration, including physical isolation from electric motors, devices, lighting fixtures, and the like. National Electrical Code standards and this Chapter are minimum requirements for DoD buildings and areas containing explosives.

B. Hazardous locations

National Electrical Code definitions of Class I, Division 1, and Class II, Division 1, hazardous locations are modified as follows for DoD explosives applications:

1. Areas containing explosives dusts or explosives that may through handling produce dust capable of being dispersed in the atmosphere shall be regarded as Class II, Division 1, hazardous locations.

2. Areas in which explosives sublimation or condensation may occur shall be regarded as both Class I, Division 1, and Class II, Division 1, hazardous locations.

C. Special occupancies

1. To ensure assignment to the proper hazardous location, class and group, it is necessary to have knowledge of the properties of explosives involved. Minimum requirements include sensitivity to heat and spark and thermal stability. If the properties of an explosive are such that Class I or Class II, or both, provide inadequate protection under prevailing conditions, use of any of the following approaches is acceptable: intrinsically safe equipment, purged or pressurized and suitably temperature-limited equipment, exclusion of electrical equipment from the hazardous atmosphere, or isolation of equipment from the hazardous atmosphere by means of dust, vapor, or gas-free enclosures with surface temperatures positively maintained at safe levels.

2. **Underground storage facilities**. All wiring and electrical equipment in underground storage facilities must, in addition to any other requirements of this chapter, be of moisture and corrosion resistant materials and construction unless a site specific analysis indicates that such construction is not necessary. Underground facilities must have emergency lighting systems to provide minimum illumination in the event of a power failure.

D. Static electricity

Personnel and equipment in hazardous locations (section B., above) and locations where static sensitive electroexplosive devices (EEDs) are exposed shall be grounded in a manner to effectively discharge static electricity so as to prevent accumulations that are capable of initiating the dusts, gases, vapors, or exposed EEDs. Also, permanent equipment in contact with conductive floors and table tops are not to be regarded as adequately grounded. All grounds, including static grounds, shall be interconnected if a structure is equipped with a lightning protection system.

E. Electric supply systems

There may be mutual hazards when PESs are located near electric supply lines. To protect against these hazards, the following separation requirements apply to all new construction:

1. Electric lines serving explosives operating facilities shall be installed underground from a point not less than 50 feet away from such facilities.

2. Overhead electric service lines shall be no closer to a potential explosion site (PES) of combustible construction or an open PES that the length of the lines, unless an effective means is provided to ensure that energized lines on breaking cannot come into contact with the facility or its appurtenances.

3. Electric distribution lines (those carrying less than 69 KV), the tower or poles supporting those lines, and unmanned electrical substations shall be no closer to PESs than public traffic route distances.

4. Electric transmission lines (those carrying 69 KV or more) and the tower or poles supporting them shall be located no closer to PESs than:

a. Inhabited building distance if the line in question is part of a grid system serving a large off-base area.

b. Public traffic route distance if loss of the line will not create serious social or economic hardships. (Public traffic route and inhabited building distances shall be based on airblast overpressure only; fragment distances will not be used.)

5. Electric transmission lines which can be interrupted without loss of power, i.e., power is rerouted through existing lines and/or networks, will be separated from explosives sites in accordance with subsection E.2., above.

CHAPTER 7

LIGHTNING PROTECTION

A. Policy

This Chapter defines minimum explosives safety criteria for the design, maintenance, testing and inspection of lightning protection systems. Properly maintained lightning protection is required (with exceptions) for ammunition and explosives facilities. If other lightning protection systems for these facilities are used, they shall offer equivalent protection to the types prescribed in this Chapter.

B. References

Refer to the National Fire Protection Association Lightning Protection Code, NFPA 780 (reference (m)), the National Electrical Code, NFPA 70 (reference (l)), and MIL-HDBK-419 (reference (n)).

C. Lightning protection system design

1. **Lightning protection systems**. Lightning systems must feature air terminals, low impedance paths to ground, sideflash protection, surge suppression or grounding of all conductive penetrations into the protected area, and earth electrode systems. Structural elements of the building may serve as air terminals, down conductors, or the earth electrode. Lightning protection systems used to protect DoD ammunition must be designed to intercept lightning at a 100 ft or less striking distance arc in accordance with NFPA 780 (reference (m)).

a. **Air terminals**. An air terminal is a component of a lightning protection system that is able to safely intercept lightning strikes. Air terminals may include overhead wires or grids, vertical spikes, or a building's grounded structural elements. Air terminals must be capable of safely conducting a lighting strike.

b. **Down conductors**. Down conductors (flat or round) provide low impedance paths from the air terminals described above to the earth electrode (ground) system. Structural elements having a high current capacity and a low impedance to ground need not be augmented with wires. Where wires are used as down conductors, these shall meet the requirements of NFPA 780 (reference (m)).

c. **Sideflash protection**. Protection from side flash caused by lightning shall be obtained by either separation distance or bonding in accordance with NFPA 780 (reference (m)), except as modified herein.

(1) Fences and railroad tracks located within six feet of a structure's lightning protection system shall be bonded to the structure's lighting protection system.

(2) The reinforcing bars in adjacent structural elements must be joined in a manner to provide electrical bonding between the elements. This is an absolute requirement for facilities that are used to store ammunition. Techniques commonly used and approved in the construction

industry to join reinforcing steel are acceptable for this purpose. The steel arch of an earth-covered magazine must be similarly joined to the rebar in the floor.

d. **Surge protection for incoming conductors**. A lightning protection system shall include surge protection for all incoming conductors. The surge protection must include suppression at the entrance to the building from each wire to ground. Shielded cabling, power cabling, communication lines, and electrical conduit shall be buried underground in conduit for a minimum of 50 feet before entering the structure. All other metallic utility lines and pipes must be electrically connected to the lightning protection system or the structural steel of the building just before they enter the building.

e. **Earth electrode system**. Earth electrode systems dissipate the current from a lightning strike to ground. Earth electrode systems may be Ufer grounds, ground loop conductors, radials, grounding rods, ground plates, a cable immersed in nearby salt water, chemical grounds that are installed for the purpose of providing electrical contact with the earth, or combinations of these.

D. Inspection, testing and training

1. **Visual inspection**. The lightning protection system shall be periodically inspected at a frequency determined by each Service. Visual inspections shall be conducted at least yearly.

2. **Electrical tests**. The lightning protection systems shall be periodically tested electrically as specified in paragraphs D.2.a. and D.2.b., below. Electrical testing shall be accomplished at least every two years.

a. **Bonding (resistance) tests**. Bonding (resistance) tests shall be conducted periodically (or after facility modification that may affect bonding). A maximum resistance value of one ohm is permitted across all bonds.

b. **Resistance to earth tests**. Resistance to earth tests of the lightning protection system shall be conducted periodically during the same season of the year (or after facility modification that may have affected the system).

3. **Records**. Records of resistance to earth tests shall be kept on file for the last six inspection cycles. These records shall be reviewed for trend analysis.

4. **Training**. Personnel responsible for maintenance, inspection and testing must be familiar with the fundamentals described in NFPA 780 (reference (m)) and herein as they relate to explosives facilities to ensure requirements of subsections D.1. and D.2., above, are met.

E. Lightning protection exceptions

Properly maintained lighting protection is required for ammunition and explosives facilities, with the follow exceptions:

1. Explosives operations served by a local lightning warning system to permit operations to be terminated before the incidence of an electrical storm, if all personnel can and will be provided with protection equivalent to public traffic route distance, and the damage from a lighting strike is acceptable to the Military Service.

2. Facilities containing only ammunition or explosives that cannot be initiated by lightning, as determined by the DoD Components concerned and approved by DDESB, and where no fire hazard exists.

3. Facilities where personnel are not expected to sustain injury and at the same time, the resulting economic loss of the structure, its contents and/or surrounding facilities is minimal.

CHAPTER 8

HAZARD IDENTIFICATION FOR FIRE FIGHTING

A. Scope and applicability

1. This Chapter establishes standard firefighting hazard identification measures to ensure a minimum practicable risk in fighting fires of ammunition and explosives. These identification measures are based on the classification of fires into four fire divisions according to the hazard they present.

2. Firefighting procedures, training of firefighting personnel, the use and maintenance of firefighting equipment and vehicles, the provision of water supply and alarm systems, the first aid measures, and other measures required in firefighting are outside the scope of this Chapter and shall be the responsibility of the DoD Components.

3. The ammunition hazard symbols and supplemental symbols including chemical agent symbols (see section D., below) are for firefighting situations only and are not necessarily applicable to normal operating conditions.

B. Fire divisions

1. The fire divisions are the same as Hazard Divisions 1.1 through 1.6 of Chapter 3 and are numbered serially from 1 to 6.

2. Fire division 1 indicates the greatest hazard. The hazard decreases with ascending fire division numbers from 1 to 4. Fire divisions 5 and 6 refer to explosion hazards from less sensitive substances and extremely insensitive articles, respectively.

Fire Division	Hazard involved
1	Mass explosion
2	Explosion with fragment hazard
3	Mass fire
4	Moderate fire
5	Mass explosion (blasting agents)
6	Nonmass explosion (EIDS article)

C. Fire division symbols

1. The six fire divisions are indicated by four distinctive symbols in order to be recognized by the firefighting personnel approaching the fire scene. A fire division number is shown on each symbol. Because of similar firefighting hazards, the Fire Division 1 fire symbol and number are also used for Fire Division 5 and the Fire Division 2 fire symbol and number are also used for Fire Division 6. For the purpose of identifying these symbols from long range, the symbols differ in shape as follows:

Shape	Fire Division Symbol
Octagon	1
Cross	2
Inverted triangle	3
Diamond	4

2. The color of all four symbols is orange. The color of each number identifying the applicable fire division is black. This requirement is in accordance with the color on North Atlantic Treaty Organization (NATO), United Nations Organizations (UNO), and International Maritime Organization (IMO) labels for Class 1 (explosives).

3. The shape and size of the four fire division symbols and numbers are shown in Figure 8-1. For application on doors or lockers inside buildings half-sized symbols may be used.

4. Posting of firefighting symbols on nuclear, chemical, or conventional weapon storage sites is at the discretion of the DoD Components. This recognizes that under some conditions security considerations may make it undesirable to identify munitions with fire symbols at the actual storage locations.

5. At the option of the DoD Component concerned, supplemental symbols to indicate special hazards, such as those of toxic chemicals, may be used in addition to the firefighting symbols specified in this Chapter (see Figure 8-3).

D. Chemical agent and ammunition hazard symbols

1. The storage of chemical agents and ammunition requires the use of chemical hazard symbols. These symbols shall be used by themselves or in conjucttion with fire symbols as appropriate.

2. The chemical hazard symbols are illustrated in Figure 8-2. Supplemental chemical hazard symbols are circular in shape, are yellow with black letters, and are illustrated in Figure 8-3. Subsections D.3. through D.8., below, further describe these symbols, the hazards indicated by the symbols, and recommended protective clothing and equipment to be used for fighting fires. Protective clothing requirements for other than firefighting situations shall be determined by the DoD Components.

3. When the chemical hazard symbol ordering the wearing of full protective clothing (symbol 1 of Figure 8-2) is colored with a red rim and figure, the symbol indicates the presence of highly toxic chemical agents which may cause death or serious damage to body functions. The following full protective clothing, identified as set 1 in Figure 8-2 and column 3 of Table 8-1 shall be used: M9 series protective gas mask, impermeable suit, impermeable hood, impermeable boots, undergarments, coveralls, protective footwear, and impermeable gloves.

4. When the chemical hazard symbol ordering the wearing of full protective clothing (symbol 1 of Figure 8-2) is colored with a yellow rim and figure, the symbol indicates the presence of harassing agents (riot control agents and smokes). The following protective clothing, identified as set 2 in Figure 8-2 and column 4 of Table 8-1, shall be used: M9 or M17 series protective gas masks or self-contained breathing apparatus (SCBA), permeable coveralls, and protective gloves.

5. When the chemical hazard symbol ordering the wearing of full protective clothing (symbol 1 of Figure 8-2) is colored with a white rim and figure, the symbol indicates the presence of WP and other spontaneously combustible material. The following protective clothing, identified as set 3 in Figure 8-2 and column 5 of Table 8-1, shall be used: flame-resistant coveralls, flame-resistant gloves, M9 or M17 series protective gas masks or SCBA.

6. The chemical hazard symbol ordering the wearing of breathing apparatus (symbol 2 of Figure 8-2) indicates the presence of incendiary and readily flammable chemical agents that present an intense radiant heat hazard. Protective masks shall be used to prevent inhalation of smoke from burning incendiary mixtures.

7. Firefighting personnel equipped with normal heat-resistant clothing (bunker suit) and gas mask or SCBA do not require the protective clothing identified as sets 2 and 3 when fighting fires involving material in which sets 2 or 3 are specified in Table 8-1.

8. The chemical hazard symbol warning against applying water (symbol 3 of Figure 8-2) indicates a dangerous reaction will occur if water is used in an attempt to extinguish fire.

9. The chemical hazard symbol prohibiting the use of water in fire-fighting may be placed together with any one of the other symbols if required.

10. The supplemental chemical hazard symbols described in Figure 8-3 shall be used with other symbols as required to identify chemical agents having special chemical hazards.

11. The chemical agents most used in ammunition, the compatibility groups of that ammunition, and the chemical hazard symbols required in storage are specified in Table 8-1.

E. Firefighting measures

1. Firefighters of ammunition and explosives fires shall have a thorough knowledge of the specific reactions of ammunition and explosives exposed to the heat or to the fire itself. The firefighting forces and other essential personnel shall be briefed before approaching the scene of the fire. They shall be informed of the known hazards and conditions existing at the scene of the fire before proceeding to the location of the fire.

2. Fire involving ammunition and explosives shall be fought according to the hazard classification, fire division, the stage of the fire, and the procedures specified by the DoD Component concerned. Special firefighting instructions addressing ammunition hazards shall be developed according to the needs of the DoD Components.

3. All fires starting in the vicinity of ammunition or explosives shall be reported and shall be fought immediately with all available means and without awaiting specific instructions. However, if the fire involves explosive material or is supplying heat to it, or if the fire is so large that it cannot be extinguished with the equipment at hand, the personnel involved shall evacuate and seek safety.

4. Emergency withdrawal distances for nonessential personnel are intended for application in emergency situations only and are not to be used for facility siting. Emergency withdrawal distances depend on fire involvement and on whether or not the hazard classification, fire division and quantity of explosives are known. The withdrawal distance for essential personnel at

accidents shall be determined by emergency authorities on site. Emergency authorities shall determine who are essential personnel.

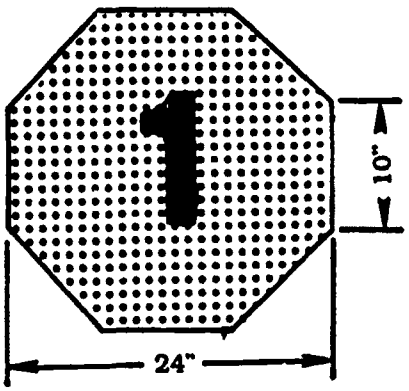
5. If a fire involves explosives or involvement is imminent, then the initial withdrawal distance applied shall be at least the inhabited building distance while the appropriate emergency withdrawal distance for nonessential personnel is being determined. When emergency authorities determine that the fire is or may become uncontrollable and may result in deflagration and/or detonation of nearby ammunition or explosive material, all nonessential personnel shall be withdrawn to the appropriate emergency withdrawal distance listed in Table 8-2. If fire is not affecting explosives or involvement is not imminent, then emergency authorities shall determine the withdrawal distance based on the situation at hand.

6. Structures or protected locations offering equivalent protection for the distances listed in Table 8-2 may be used in lieu of relocating personnel from the structure and/or location to the specified emergency withdrawal distance.

7. Commanders will develop evacuation plans for their installations that reference the appropriate withdrawal distances as part of the disaster response plan. The Commander is responsible for alerting civilian authorities of any imminent explosive accident on the installation that may affect the local community and for providing these authorities with the appropriate emergency withdrawal distances.

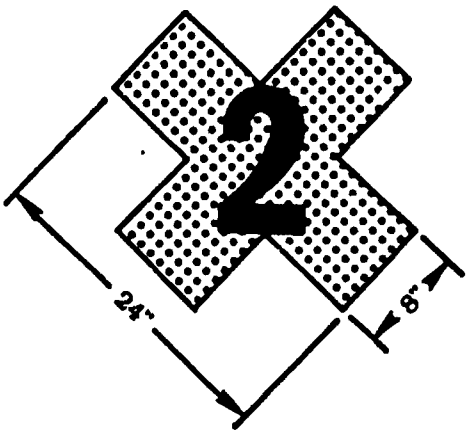
8. Ammunition containing both explosives and chemical agents (see Table 8-1) requires special attention and precautions in firefighting. Fires involving such ammunition shall be fought in accordance with their fire division characteristics, but responding personnel must also take into account the potential additional hazards and precautions discussed in Chapter 11 relating to the effects of the chemical agents involved.

9. Entry to underground storage facilities following a fire or explosion requires special precautions. Monitoring for the presence of toxic fumes, oxygen depleted atmospheres and structural damage shall be performed during initial entry following an accident. Commanders will develop written procedures that define actions to be taken in such emergency situations.



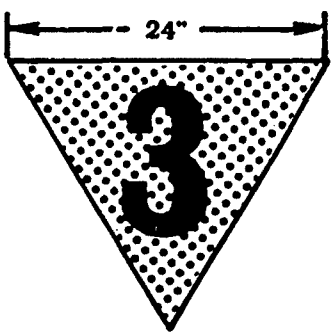
Fire Division 1 or 5

24" NSN - 7690 - 01 - 082 - 6290
12" NSN - 7690 - 01 - 081 - 9581



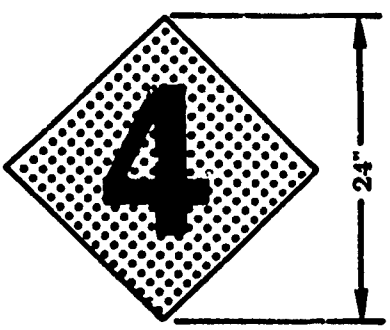
Fire Division 2 or 6

24" NSN - 7690 - 01 - 082 - 0289
12" NSN - 7690 - 01 - 087 - 7340



Fire Division 3

24" NSN - 7690 - 01 - 081 - 9583
12" NSN - 7690 - 01 - 081 - 9582

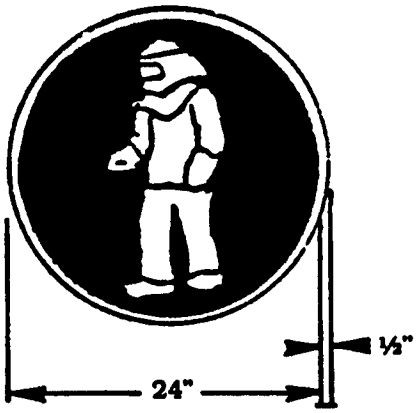


Fire Division 4

24" NSN - 7690 - 01 - 082 - 6709
12" NSN - 7690 - 01 - 081 - 9584

BACKGROUND: Orange #12246 (Fed. Std. 595A)
NUMBERS: 10" High and 2" Thick Black #17038 (Fed. Std. 595A)

Figure 8-1. Fire Division Symbols



Symbol 1. Wear full protective clothing

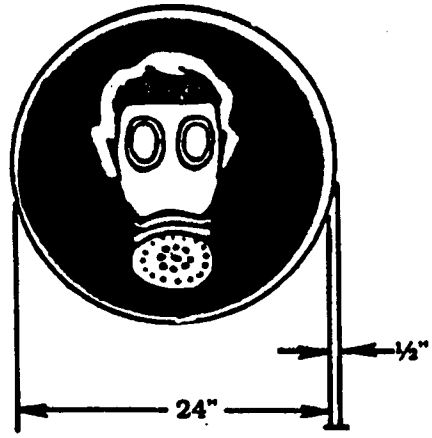
Background is blue.
Figure and rim is:

Red for Set 1 Protective Clothing
24" NSN-7690-01-081-9586
12" NSN-7690-01-081-9585

Yellow for Set 2 Protective Clothing
24" NSN-7690-01-081-9587
12" NSN-7690-01-082-0281

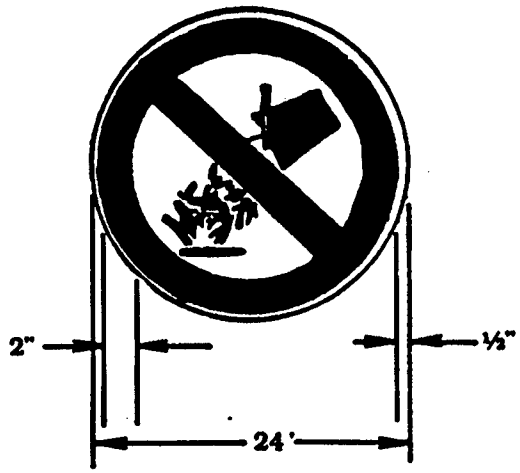
White for Set 3 Protective Clothing
24" NSN-7690-01-083-6272
12" NSN-7690-01-081-9588

Colors per Fed. Std. 595A
or GSA Catalog:
Red #11105
Blue #15102
Yellow #13538
White #17875
Black #17038



Symbol 2. Wear Breathing Apparatus

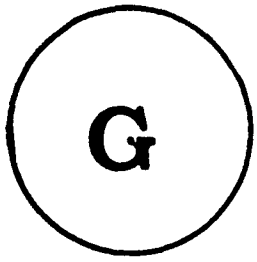
Background is blue.
Figure and rim are white.
24" NSN-7690-01-081-9589
12" NSN-7690-01-082-6710



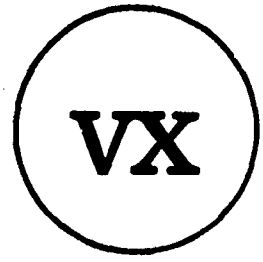
Symbol 3. Apply no water

Background is white, circle and diagonal are red, figures are black.
24" NSN-7690-01-082-2254
12" NSN-7690-01-082-0292

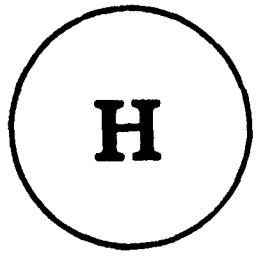
Figure 8-2. Chemical Hazard Symbols



1. G-Type Nerve Agents
24" NSN - 7690 - 01 - 082 - 5418
12" NSN - 7690 - 01 - 081 - 7481



2. VX Nerve Agents
24" NSN - 7690 - 01 - 081 - 7483
12" NSN - 7690 - 01 - 081 - 7482



3. H-Type Mustard Agents
24" NSN - 7690 - 01 - 082 - 6713
12" NSN - 7690 - 01 - 083 - 1663

All Symbols with Black Letters 12" High on 24" Dia. Yellow Circle.

(Colors per Fed. Std. 595A: Black #17038 and Yellow #13538)

Figure 8-3. Supplemental Chemical Hazard Symbols

Table 8-1. Compatibility Group and Chemical Hazard Symbols Required for Storage of Chemical Ammunition and Substances.

Chemical Ammunition and Substances	Compatibility Group[2]	Full Protective Clothing			Breathing Apparatus	Apply No Water
		Set 1	Set 2	Set 3		
1	2	3	4	5	6	7
Toxic Agents[1]	K	X				
Tear Gas, O-Chlorobenzol	G		X			
Smoke, Titanium Tetrachloride (FM)	G		X			
Smoke, Sulpher trioxide-chlorosulphonic acid solution (FS)	G		X			
Smoke, Aluminum-zinc oxide-hexachloroethane (HC)	G				X	X
White Phosphorous (WP)	H			X		
White Phosphorous plasticized (PWP)	H			X		
Thermite or Thermate (TH)	G				X	X
Pyrotechnic Material (PT)	G				X	X
Calcium Phosphide	L				X	X
Signaling Smokes	G				X	
Isobutyl methacrylate with oil (IM)	J				X	
Napalm (NP)	J			X	X	X
Triethylaluminim (TEA)(TPA)	L			X		X

Notes:

1 Toxic Agents without explosives components that normally would be assigned to Hazard Division 6.1 may be stored as compatibility group K.

2 See Chapter 3.

Table 8-2. Emergency Withdrawal Distances for Nonessential Personnel.

Hazard Division	Unknown Quantity	Known Quantity
Unknown, located in facility, truck and or tractor trailer	approximately 3/4 mile (4,000 ft)	4,000 ft
Unknown, located in railcar	approximately 1 mile (5,000 ft)	5,000 ft
1.1 (Explosive A) and 1.5 (See note 1)	Same as unknown facility, truck trailer or railcar as appropriate	For transportation, use 2,500 ft minimum distance for 500 lb and below. Above 500 lb, for rail cars use 5,000 ft minimum distance; otherwise use 4,000 ft minimum distance. Use 4,000 ft minimum distance for bombs and projectiles with caliber 5 inch or greater. For facilities, use 2,500 ft minimum distance for 15,000 lb and below. Use 4,000 ft minimum distance for net explosive weights above 15,000 lb and less than or equal to 50,000 lb. Above 50,000 lb, use d (distance) = 105 $W^{1/3.}$
1.2 (Explosive A) and 1.6 (See note 1)	2,500 ft	2,500 ft
1.3 (Explosive B) (See note 2)	600 ft	Twice the inhabited building distance (Table 9-10) with a 600 ft minimum range.
1.4 (Explosive C)	300 ft	300 ft

Notes:

1 For Hazard Division 1.1 and 1.2 items, if known, the maximum range fragments and debris will be thrown (including the interaction effects of stacks of items, but excluding lugs, strongbacks, and/or nose and tail plates) may be used to replace the minimum range.

2 For accidents involving propulsion units, it is not required to specify emergency withdrawal distances based upon the potential flight ranges of these items.

CHAPTER 9

QUANTITY-DISTANCE

A. General

The damage or injury potential of explosions is normally determined by the prevailing distance between the PES and the ES; the ability of the PES to suppress blast overpressure, primary and secondary fragments, and debris; and the ability of the ES to resist explosion effects. This Chapter sets minimum standards for separating a PES from an ES that take into account anticipated explosion effects suppression and resistance. Q-D relationships are established for related and unrelated PESs and explosives and nonexplosives ESs.

B. Establishment of quantity of explosives and distances

1. **Quantity of explosives**. The total quantity of explosives in a magazine, operating building, or other explosives facility shall be the net weight of the explosives calculated upon the following bases (such calculations are intended for use with the tables in these standards):

a. **Mass-detonating explosives**. NEW.

b. **Nonmass-detonating explosives**

(1) **Propellants**. The net propellant weight.

(2) **EIDS**. The net EIDS weight.

(3) **Pyrotechnic items**. The sum of the weight of the pyrotechnic composition and the explosives involved. Dyes and colored smoke loaded in pyrotechnics are excluded.

(4) **Bulk metal powders and pyrotechnic composition**. The sum of the net weights of metal powders and pyrotechnic composition in containers.

(5) **Other ammunition**. The weight of HE or EIDS plus a suitable contribution, if any, from propellant, pyrotechnic components, or expelling charges. See Chapter 3 for hazard classification testing requirements. Groups A and B chemical agent (see subsection H.1., Chapter 11), colored and HC smoke, dyes, irritants, white phosphorus, plasticized white phosphorus, and pyrophoric agent TPA loaded in munitions are excluded.

c. When Hazard Divisions 1.1 and 1.2 are located in the same site, determine the distances for the total quantity considered first as 1.1 and then as 1.2. The required distance is the greater of the two. When the 1.1 requirements are controlling and the HE equivalence of the 1.2 is known (data to support the HE equivalence has been approved by the DDESB) the HE equivalent weight of the 1.2 items may be added to the total explosive weight of 1.1 items to determine the NEW for 1.1 distance determination; otherwise, the total explosive weight of the 1.2 items (including the net propellant weight) is to be added to the total explosive weight of the 1.1 items to determine the NEW for 1.1 distance determination.

d. When Hazard Divisions 1.1 and 1.3 are located in the same site, determine the distances for the total quantity as 1.1. However, when the HE equivalence of the 1.3 is known

(data to support the HE equivalence has been approved by DDESB) the HE equivalent weight of the 1.3 items may be added to the total explosive weight of 1.1 items to determine the NEW for 1.1 distance determinations; otherwise the total net propellant weight of the 1.3 items is to be added to the total explosive weight of the 1.1 items to determine the NEW for 1.1 distance determinations.

e. When Hazard Divisions 1.2 and 1.3 are located in the same site, determine the required distance for each separately. The two quantities do not need to be added together for Q-D purposes. The required distance is the greater of the two.

f. When Hazard Divisions 1.1, 1.2, and 1.3 are located in the same site, determine the distances for the total quantity considered first as 1.1, next as 1.2, and finally as 1.3. The required distance is the greatest of the three. As permitted by paragraphs B.1.c. and B.1.d., above, HE equivalent weights for 1.2 and 1.3 items may be used in NEW determinations for Q-D purposes; otherwise the rules for adding total explosive (and/or propellant) weight of 1.2 and 1.3 items is to be added to the explosive weight of the 1.1 items (when controlling) to determine the NEW for 1.1 distance requirements.

g. Explosives designated as Hazard Division 1.5 for transportation are considered to be Hazard Division 1.1 for Q-D purposes (storage).

h. When Hazard Division 1.6 is located with Hazard Division 1.1 or 1.5, Hazard Division 1.6 is considered Hazard Division 1.1 for Q-D purposes. When Hazard Division 1.6 is located with Hazard Division 1.2, Hazard Division 1.6 is considered Hazard Division 1.2 for Q-D purposes.

i. When Hazard Division 1.6 is located with Hazard Division 1.3, then add the explosives weight of the Hazard Division 1.6 to the weight of Hazard Division 1.3 and determine the distances for the total quantity considered first as Hazard Division 1.3 (if demonstrated by testing or analogy; otherwise, treat as Hazard Division 1.1) and second as Hazard Division 1.6. The required distance is the greater distance of the two.

j. The Q-Ds for Hazard Division 1.1, 1.2, 1.3, 1.5 or 1.6 individually or in combination are not affected by the presence of Hazard Division 1.4.

k. If DDESB approved buffer configurations are provided, the NEW for Q-D purposes is the explosives weight of the largest stack plus the explosives weight of the buffer material.

2. **Q-D computations and determinations**

a. Throughout these standards, NEW is used to calculate distance by means of formula of the type $D = K \cdot W^{1/3}$, when D is the distance in feet, K is a factor depending upon the risk assumed or permitted, and W is the NEW in pounds. When metric units are used, the symbol Q denotes NEQ in kilograms. In the formula $D = K \cdot Q^{1/3}$, the distance D is expressed in meters. Thus, the respective units of K are $ft/lb^{1/3}$ and $m/kg^{1/3}$ in the two systems. The value of K in English units is approximately 2.5 times its value in metric units. For example, if $D(m) = 6 \cdot Q^{1/3}$, then $D(ft) = 15 \cdot W^{1/3}$. Distance requirements determined by the formula with English units are sometimes expressed by the value of K, using the terminology K9, K11, K18, to mean K = 9, K = 11, and K = 18.

b. The quantity of explosives in a magazine, operating building, or other explosives site shall be considered the net weight of the controlling class of explosives contained therein (the class requiring the greatest separation).

(1) Extensive tests and analytical work have proven that when two or more stacks of equal amounts of mass-detonating explosives detonate within short time intervals (the time in milliseconds is less than 4.0 times the cube root of the explosive weight of any one stack in pounds for lateral target positions and less than 5.6 times the cube root of the explosive weight in pounds for axial target position) the blast waves will coalesce. The combined shock wave, after coalescence, will be that of a single detonation of a charge equal to the summation of the several stacks. The actual separation time between successive detonations is influenced by the spatial separation of explosives, geometry, and distribution, the character of the dividing wall or other barrier between, and the sensitivity of the explosives.

(2) When it is considered advantageous for Q-D computations to subdivide a total quantity of mass-detonating explosives into smaller units, it shall be ensured by construction of a suitable barrier or provision of adequate separation that there will be no propagation from one to another. Design of intervening barriers in accordance with the principles contained in TM 5-1300, AFM 88-22, NAVFAC P-397 (reference (g)) will satisfy this requirement. If this requirement is met, the explosive content of the subdivision requiring the greatest distance will govern. If this requirement is not met, Q-D computations must be based upon the summation of the mass-detonating explosives in all of the subdivisions.

c. The quantity of explosives to be permitted in each of two or more locations shall be determined by considering each location as a potential explosion site. The quantity of explosives to be permitted in each of these locations shall be the amount permitted by the distance specified in the appropriate Q-D tables considering each as a potential target site in turn, except for service magazines (see paragraphs D.1.i. and D.2.h., Chapter 2).

d. Interpolation and extrapolation of Q-D specified in Table 9-1 shall be in accordance with footnotes to the table, except that minimum distances for specific weapons listed in Table 9-2 may apply. Interpolation and extrapolation of Tables 9-3, 9-4 and 9-5 shall be accomplished by use of columnar formulae cited in the tables.

e. It is impractical to specify Q-D separations allowing for the designed flight range of propulsive units (rockets, missile motors, and catapults) that properly belong in Hazard Division 1.1, 1.2, or 1.3. Therefore, maximum designed flight ranges for units in a propulsive state shall be disregarded. The distance required to protect from fragments in credible accident situations, however, shall be established in accordance with the principles in section E., Chapter 2.

f. Measurements of distance for determining the maximum allowable quantity of explosives shall be made from the nearest wall of the structure containing explosives, or exterior of the nearest wall of the controlling subdivision when the structure is subdivided so that mass detonation between subdivisions will not occur, to the nearest part of an exposed structure or site. Separation distances are measured along straight lines. For large intervening topographical features such as hills, measure over or around the feature, whichever is the shorter. For golf courses, measure to the nearest edge of the tee or green and the centerline of fairways.

g. When railroad cars or motor vehicles containing ammunition and explosives are not separated from operating buildings, magazines, or open storage sites containing ammunition and explosives in such a manner as to prevent their mass detonation, the total quantity of explosives (see subsection B.1., above) in such locations, railcars, and motor vehicles shall be considered as a unit and the separation distance measured from the nearest outside wall of the building, railcar, vehicle, or edge of open stack, as appropriate, to a target. If the explosives are separated into smaller units so that mass detonation of the explosives in the railcars and motor vehicles and inside the units will not occur, the separation distance shall be measured from the nearest controlling explosives unit, railcar, or vehicle to a target.

C. Hazard division Q-D tables

1. Hazard Division 1.1

a. **Inhabited building and public traffic route distances.** Separation distances required from standard earth-covered magazines and other types of PESs to inhabited buildings and public traffic routes are listed for various quantities of Hazard Division 1.1 in Table 9-1. Specified separations from standard earth-covered magazines take into account reductions in blast overpressure attributable to the earth cover of the magazines. Permissible exposures at these distances are listed in subsections D.3., D.4., D.5. and D.6., Chapter 2.

b. **Intraline distance.** Separation distances required between explosives and nonexplosives buildings and sites within an explosives operating line are listed for various quantities of Hazard Division 1.1 in Table 9-3. Provisions of subsection B.2., above, shall be used in applying this table except that the distance required between an explosives operating building and its service magazines is determined by the quantity of explosives in the service magazines irrespective of the quantity in the operating building. Permissible exposures at intraline distances are listed in subsections D.1. and D.2. of Chapter 2.

c. **Intraline distance from earth-covered magazines.** Testing has shown some attenuation of the airblast overpressure occurs at the sides and rear of earth-covered magazines relative to the unconfined surface burst configuration. Some slight overpressure increase occurs at the front. To account for this attenuation, the 12 psi (Barricaded) and 3.5 psi (Unbarricaded) Intraline Distances from earth-covered magazines are given according to the factors presented below. The values are tabulated in Table 9-4.

Exposure	NEW Range (lbs)	Vice K9	Vice K18
Front	1 - 300K[1]	10	18
	300 - 500K	10 - 9	18
Side	1 - 300K	7	16
	300 - 400K	7 - 9	16 - 18
	over 400K	9	18
Rear	1 - 100K	6	12
	100K - 300K	6	12 - 14
	300K - 400K	6 - 9	14 - 18
	over 400K	9	18

[1]300K = 300,000

Table 9-1. Hazard Division 1.1, Inhabited Building and Public Traffic Route Distances. (See Notes)

Net Explosive Weight (NEW) lbs	Distance in Feet to Inhabited Building From:				Distance in Feet to Public Traffic Route From:			
	Earth-covered Magazine			Other	Earth-covered Magazine			Other
	Front	Side	Rear	PES	Front	Side	Rear	PES
Col 1	Col 2[1,8]	Col 3[1,8]	Col 4[2,8]	Col 5[3]	Col 6[4,8]	Col 7[5,8]	Col 8[6,8]	Col 9[7]
1	500	250	250	1,250	300	150	150	750
2	500	250	250	1,250	300	150	150	750
5	500	250	250	1,250	300	150	150	750
10	500	250	250	1,250	300	150	150	750
20	500	250	250	1,250	300	150	150	750
30	500	250	250	1,250	300	150	150	750
40	500	250	250	1,250	300	150	150	750
50	500	250	250	1,250	300	150	150	750
100	500	250	250	1,250	300	150	150	750
150	500	250	250	1,250	300	150	150	750
200	700	250	250	1,250	420	150	150	750
250	700	250	250	1,250	420	150	150	750
300	700	250	250	1,250	420	150	150	750
350	700	250	250	1,250	420	150	150	750
400	700	250	250	1,250	420	150	150	750
450	700	250	250	1,250	420	150	150	750
500	1,250	1,250	1,250	1,250	750	750	750	750
600	1,250	1,250	1,250	1,250	750	750	750	750
700	1,250	1,250	1,250	1,250	750	750	750	750
800	1,250	1,250	1,250	1,250	750	750	750	750
900	1,250	1,250	1,250	1,250	750	750	750	750
1,000	1,250	1,250	1,250	1,250	750	750	750	750
1,500	1,250	1,250	1,250	1,250	750	750	750	750
2,000	1,250	1,250	1,250	1,250	750	750	750	750
3,000	1,250	1,250	1,250	1,250	750	750	750	750
4,000	1,250	1,250	1,250	1,250	750	750	750	750
5,000	1,250	1,250	1,250	1,250	750	750	750	750
6,000	1,250	1,250	1,250	1,250	750	750	750	750
7,000	1,250	1,250	1,250	1,250	750	750	750	750
8,000	1,250	1,250	1,250	1,250	750	750	750	750
9,000	1,250	1,250	1,250	1,250	750	750	750	750
10,000	1,250	1,250	1,250	1,250	750	750	750	750
15,000	1,250	1,250	1,250	1,250	750	750	750	750
20,000	1,250	1,250	1,250	1,250	750	750	750	750
25,000	1,250	1,250	1,250	1,250	750	750	750	750
30,000	1,250	1,250	1,250	1,250	750	750	750	750
35,000	1,250	1,250	1,250	1,310	750	750	750	785
40,000	1,250	1,250	1,250	1,370	750	750	750	820

Table 9-1. Hazard Division 1.1, Inhabited Building and Public Traffic Route Distances. (See Notes)

Net Explosive Weight (NEW) lbs	Distance in Feet to Inhabited Building From:				Distance in Feet to Public Traffic Route From:			
	Earth-covered Magazine			Other	Earth-covered Magazine			Other
	Front	Side	Rear	PES	Front	Side	Rear	PES
Col 1	Col 2[1,8]	Col 3[1,8]	Col 4[2,8]	Col 5[3]	Col 6[4,8]	Col 7[5,8]	Col 8[6,8]	Col 9[7]
45,000	1,250	1,250	1,250	1,425	750	750	750	855
50,000	1,290	1,290	1,250	1,475	775	775	750	885
55,000	1,330	1,330	1,250	1,520	800	800	750	910
60,000	1,370	1,370	1,250	1,565	820	820	750	940
65,000	1,405	1,405	1,250	1,610	845	845	750	965
70,000	1,440	1,440	1,250	1,650	865	865	750	990
75,000	1,475	1,475	1,250	1,685	885	885	750	1,010
80,000	1,510	1,510	1,250	1,725	905	905	750	1,035
85,000	1,540	1,540	1,250	1,760	925	925	750	1,055
90,000	1,570	1,570	1,250	1,795	940	940	750	1,075
95,000	1,595	1,595	1,250	1,825	960	960	750	1,095
100,000	1,625	1,625	1,250	1,855	975	975	750	1,115
110,000	1,740	1,740	1,290	1,960	1,045	1,045	770	1,175
120,000	1,855	1,855	1,415	2,065	1,110	1,110	850	1,240
125,000	1,910	1,910	1,480	2,115	1,165	1,165	890	1,270
130,000	1,965	1,965	1,545	2,165	1,180	1,180	925	1,300
140,000	2,070	2,070	1,675	2,255	1,245	1,245	1,005	1,355
150,000	2,175	2,175	1,805	2,350	1,305	1,305	1,085	1,410
160,000	2,280	2,280	1,935	2,435	1,370	1,370	1,160	1,460
170,000	2,385	2,385	2,070	2,520	1,430	1,430	1,240	1,515
175,000	2,435	2,435	2,135	2,565	1,460	1,460	1,280	1,540
180,000	2,485	2,485	2,200	2,605	1,490	1,490	1,320	1,565
190,000	2,585	2,585	2,335	2,690	1,550	1,550	1,400	1,615
200,000	2,680	2,680	2,470	2,770	1,610	1,610	1,480	1,660
225,000	2,920	2,920	2,810	2,965	1,750	1,750	1,685	1,780
250,000	3,150	3,150	3,150	3,150	1,890	1,890	1,890	1,890
275,000	3,250	3,250	3,250	3,250	1,950	1,950	1,950	1,950
300,000	3,345	3,345	3,345	3,345	2,005	2,005	2,005	2,005
325,000	3,440	3,440	3,440	3,440	2,065	2,065	2,065	2,065
350,000	3,525	3,525	3,525	3,525	2,115	2,115	2,115	2,115
375,000	3,605	3,605	3,605	3,605	2,165	2,165	2,165	2,165
400,000	3,685	3,685	3,685	3,685	2,210	2,210	2,210	2,210
425,000	3,760	3,760	3,760	3,760	2,250	2,250	2,250	2,250
450,000	3,830	3,830	3,830	3,830	2,300	2,300	2,300	2,300
475,000	3,900	3,900	3,900	3,900	2,340	2,340	2,340	2,340
500,000	3,970	3,970	3,970	3,970	2,380	2,380	2,380	2,380

Notes for Table 9-1:

1 Bases for Columns 2 and 3 distances:

1-45,000 lbs - debris hazard - lesser distances permitted if proved sufficient to limit hazardous debris to 1/600 ft^2. Formula $d = 35W^{1/3}$ (blast overpressure) may be used if fragments and debris are absent.

45,000-100,000 lbs - blast overpressure hazard. Computed by formula $d = 35W^{1/3}$.

100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 0.3955W^{0.7227}$

250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

2 Bases for Column 4 distances:

1-100,000 lbs - debris hazard - lesser distances permitted if proved sufficient to limit hazardous debris to 1/600 ft^2. Formula $d = 25W^{1/3}$ (blast overpressure) may be used if fragments and debris are absent.

100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 0.004125W^{1.0898}$.

250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

3 Bases for Column 5 distances:

1-30,000 lbs - fragments and debris hazard. Lesser distances permitted as follows (see subparagraph E.2.c.(1) of Chapter 2): (a) thin-cased ammunition and bulk explosives with NEW to 100 lbs - 670 ft. (b) Bare explosives in the open, distances computed by formula $d = 40W^{1/3}$. Distances other than 1,250 ft. to be used when required by Table 9-2.

30,000-100,000 lbs - blast overpressure hazard. Computed by formula $d = 40W^{1/3}$.

100,000-250,000 lbs - blast overpressure hazard. Computed by formula $d = 2.42W^{0.577}$.

250,000 lbs and above - blast overpressure hazard. Computed by formula $d = 50W^{1/3}$.

4 Column 6 distances have the same hazard bases and are equal to 60 percent of Column 2 distances.

5 Column 7 distances have the same hazard bases and are equal to 60 percent of Column 3 distances.

6 Column 8 distances have the same hazard bases and are equal to 60 percent of Column 4 distances.

7 Column 9 distances have the same hazard bases and are equal to 60 percent of Column 5 distances.

8 Distances for NEWs between 30,000 and 250,000 lbs apply only for earth-covered magazines that are 26 ft. wide and 60 ft. long, or larger. For smaller earth-covered magazines, use other PES distances of Columns 5 or 9.

Table 9-2. Minimum Fragment Protection Distance for Selected Hazard Division 1.1 Items.[1]

Nomenclature	Distance Required in Feet			
Col 1	Col 2	Col 3	Col 4	Col 5
	1 Unit	2 Units	5 Units	10 Units[2]
AGM 65/A	400	500	500	500
AIM 7, Mk 38 Warhead	700	700	700	700
AIM 9	400	400	400	400
ASROC	500	[3]500		
Bomb, 750 1b, M117A2	690	820	1020	1470
Bomb, 500 lb, Mk 82	670	860	1080	1240
Chaparral	400	400	400	400
Harpoon	500			
Improved Hawk	900	900	900	900
Nike Hercules	900	1150	1150	1150
Penguin	500	[3]500		
Projectile, 175mm, M437A2	450	580	830	2070
Projectile, 155mm, M107	400	510	720	1490
Projectile, 105mm, Ml[4]	270	350	500	1000
Projectile, 8 in, Mk 25	520	750	960	1240
Projectile, 5 in, Mk 49	280	430	660	1000
Tomahawk	500	[5]600	1250	1250
Torpedoes (Navy) Not Over 1,500 lbs NEW	[6]500	[6]500	[6]500	[6]500

Notes:

1 See paragraph E.2.c. of Chapter 2.

2 Ten units or more until the point is reached at which this distance is exceeded by the distance requirements of Table 9-1.

3 This distance applies for a maximum of 3 units.

4 105mm projectiles and 105mm complete rounds not in standard storage and shipping containers are Hazard Division 1.1.

5 This distance applies for a maximum of 4 units. Missiles must be transported and/or handled only two at a time in a nose-to-tail configuration and in their launch capsule and/or shipping container, as well as aligned and/or handled so that each group of two missiles is located outside of the warhead fragment beam spray region of the other two missiles.

6 This distance applies to any torpedoes that are analogous in terms of explosive hazard to those tested; that is, MK 16 warshot.

Table 9-3. Hazard Division 1.1, Intraline Distances.

Net Expl. Wt. (lb)	Distance in Feet Hazard Factor Bar k=9	Unbar k=18	Notes	Net Expl. Wt. (lb)	Distance in Feet Hazard Factor Bar k=9	Unbar k=18	Notes
50	33	66	1	70,000	371	742	
100	42	84		75,000	380	759	
200	53	105		80,000	388	776	
300	60	120		85,000	396	791	
400	66	133		90,000	403	807	
500	71	143		95,000	411	821	
600	76	152		100,000	418	835	
700	80	160		125,000	450	900	
800	84	167		150,000	478	956	
900	87	174		175,000	503	1,007	
1,000	90	180		200,000	526	1,053	
1,500	103	206		225,000	547	1,095	
2,000	113	227		250,000	567	1,134	
3,000	130	260		275,000	585	1,171	
4,000	143	286		300,000	602	1,205	
5,000	154	308		325,000	619	1,238	
6,000	164	327		350,000	634	1,269	
7,000	172	344		375,000	649	1,298	
8,000	180	360		400,000	663	1,326	
9,000	187	374		500,000	714	1,429	2
10,000	194	388		600,000	759	1,518	
15,000	222	444		700,000	799	1,598	
20,000	244	489		800,000	835	1,671	
25,000	263	526		900,000	869	1,738	
30,000	280	559		1,000,000	900	1,800	
35,000	294	589		1,500,000	1030	2,060	
40,000	308	616		2,000,000	1134	2,268	
45,000	320	640		2,500,000	1221	2,443	
50,000	332	663		3,000,000	1298	2,596	
55,000	342	685		3,500,000	1366	2,733	
60,000	352	705		4,000,000	1429	2,857	
65,000	362	724		5,000,000	1539	3,078	

Notes:

1 For less than 50 pounds, less distance may be used when structures, blast mats and the like can completely contain fragment and debris. This table is not applicable when blast, fragments and debris are completely confined, as in certain test firing barricades.

2 Quantities above 500,000 lbs NEW are authorized only for Group IV propellant.

Table 9-4. Hazard Division 1.1, Intraline Distances from Earth-covered Magazines.

NEW (lb.)	K-9 Application (ft)			K-18 Application (ft)		
	Front	Side	Rear	Front	Side	Rear
50	35	25	20	60	60	45
100	45	30	30	80	75	55
200	60	40	35	100	95	70
300	65	45	40	120	105	80
400	75	50	45	130	120	90
500	80	55	50	140	125	95
600	85	60	50	150	135	100
700	90	60	55	160	140	105
800	90	65	55	170	150	110
900	95	70	60	175	155	115
1,000	100	70	60	180	160	120
1,500	115	80	70	210	185	135
2,000	125	90	75	230	200	150
3,000	145	100	85	260	230	175
4,000	160	110	95	290	255	190
5,000	170	120	100	310	275	205
6,000	180	125	110	330	290	220
7,000	190	135	115	340	305	230
8,000	200	140	120	260	320	240
9,000	210	145	125	370	330	250
10,000	215	150	130	390	345	260
15,000	245	175	150	450	395	295
20,000	270	190	165	490	435	325
25,000	290	205	175	530	470	350
30,000	310	220	185	560	500	370
35,000	325	230	195	590	525	390
40,000	340	240	205	620	545	410
45,000	355	250	215	640	570	425
50,000	370	260	220	660	590	440
55,000	380	265	230	680	610	455
60,000	390	275	235	700	625	470
65,000	400	280	240	720	645	480
70,000	410	290	245	740	660	495
75,000	420	295	255	760	675	505
80,000	430	300	260	780	690	520
85,000	440	310	265	790	705	530
90,000	450	315	270	810	715	540
95,000	455	320	275	820	730	545
100,000	465	325	280	840	745	555
125,000	500	350	300	900	800	605
150,000	530	370	320	960	850	650
175,000	560	390	335	1,010	895	700
200,000	585	410	350	1,055	935	745
225,000	610	425	365	1,090	975	795
250,000	630	440	380	1,135	1,005	840
275,000	650	455	390	1,170	1,040	890
300,000	670	470	400	1,200	1,070	935
325,000	675	520	465	1,240	1,135	1,035
350,000	680	570	530	1,270	1,200	1,130
375,000	685	615	600	1,300	1,265	1,230
400,000	690	665	665	1,330	1,330	1,330
500,000	715	715	715	1,430	1,430	1,430

d. **Intermagazine distances.** Magazines for Hazard Division 1.1 shall be separated one from another in accordance with Table 9-5. Magazine orientation aspects of Table 9-5, Part A, involve the following considerations:

(1) When standard earth-covered magazines containing Hazard Division 1.1 ammunition are sited so that any one is in the forward sector of another, the two must be separated by distances greater than the minimum permitted for side-to-side orientations. The forward sector, or "front", for earth covered magazines is that area 60 degrees either side of the magazine centerline with the vertex of the angle placed so that the sides of the angle pass through the intersection of the headwall and side walls. The greater distances are required primarily for the protection of door and headwall structures against blast from a PES forward of the exposed magazine, and to a lesser extent due to the directionality of effects from the source. The rear sector is that area 45 degrees to the outside of imaginary lines extending rearward from the magazine side walls. See Figure 10-1 for a diagram depicting front, side and rear sectors. When a blast wave is reflected from a surface at other than grazing incidence (side-on orientation), the overpressure may be increased substantially over the free-field value. High reflected pressure and impulse can damage doors and headwalls and propel the debris into the igloo so that explosion is communicated by impact of such debris upon the contents.

(2) Examples of siting rules relative to magazine orientations (illustrated in Figure 9-1) follow:

(a) See Figure 9-1 (a) and (b). Site A as a side-to-side ES. Site B as side-to-side ES. Orientations are to be thought of as from the PES to the ES.

(b) See Figure 9-1 (c). Site A as a side-to-front ES. Site B as a front-to-side ES.

(c) See Figure 9-1 (d). Site each magazine as a front-to-front ES. Site C as a barricaded ES. Site A and B as unbarricaded ES's.

(d) Two additional standard igloo orientations warrant analysis, namely:

1 See Figure 9-1 (e). Site A as a side-to-front ES. Site B as a front-to-side ES.

2 See Figure 9-1 (f). Site A as a side-to-front ES. Site B as a front-to-side ES.

(3) See Figure 9-1 (g). When considering relationships between earth-covered magazines and aboveground magazines, or facilities requiring intraline distances, each containing Hazard Division 1.1 ammunition or explosives, the question regarding the use of barricaded or unbarricaded distance arises. The following criteria shall apply:

(a) For siting applications, no credit is given for a barricade to the front of an ECM acting as a PES. When acting as an ES, the same ECM with a barricade to its front may be sited as a barricaded ES.

(b) For siting applications, no credit is given for a barricade to the front of an aboveground magazine acting as a PES. When acting as an ES, the same aboveground magazine with a barricade to its front may be sited as a barricaded ES.

(c) The earth-covers on the sides and rear of an earth-covered magazine may be treated as barricades for siting purposes.

(4) Other factors limiting igloo magazine storage area are:

(a) Quantities above 500,000 lb. NEW in one storage location are not authorized, except for liquid propellants.

(b) The distance given for up to 100 lb. NEW constitutes the minimum magazine spacing permitted.

(5) Standards given in subparagraphs C.1.d.(1) thru d.(4), above, apply only to the storage of Hazard Division 1.1 ammunition and explosives. Existing earth-covered magazines, regardless of orientation, meeting the construction and barricading requirements of Chapter 5 (and sited one from another for 100 lb NEW or greater of Hazard Division 1.1), may be used to their physical capacity for the storage of Hazard Divisions 1.2, 1.3, and 1.4 provided distances to other exposures comply with applicable Q-D tables.

Table 9-5. Intermagazine Hazard Factors and Distances for Hazard Division 1.1.

Use Part A of this table to find the hazard factor, K, corresponding to the type of PES and ES. Use the column for this hazard factor in Part B to determine the appropriate distance for the net explosive weight in the PES.

Part A - Hazard Factors (K)[1]

Legend: S - side; R - rear; F - front; B - barricaded; U - unbarricaded;

ECM - Earth-covered Magazine; AG - Aboveground;

PES -Potential Explosion Site; ES - Exposed Site.

From PES ⇨ To ES ⇩		ECM			AG Magazine[3]	Modules and/or Cells
		S	R	F	B or U	B
ECM [2], (7 Bar)	S	1.25	1.25	2.75	4.5	4.5
	R	1.25	1.25	2	4.5	4.5
	FU	2.75	2	6	6	6
	FB	2.75	2	6	6	6
ECM [2], (3 Bar)	S	1.25	1.25	2.75	6	6
	R	1.25	1.25	2	6	6
	FU	4.5	4.5	9	9	6
	FB	4.5	4.5	6	6	6
ECM [2], (Undefined)	S	1.25 [4] 2. [5]	1.25 [4] 2. [5]	4.5 [4] 6. [5]	6	6
	R	1.25	1.25	2	6	6
	FU	6	6	11	11	11
	FB	6	6	6	6	6
AG Magazine [3]	U	6	6	11	11	11
	B	6	6	6	6	6
Modules and/or Cells	B	1.25	1.25	6	6	1.1 [6]

Notes:

1 Except as noted, K-factors for ECMs and AG Magazines are applicable for NEW up to 500,000 lb. in the PES. NEW in a Module and/or Cell is limited to 250,000 lb..

2 Descriptions of the earth-covered magazines are in subsection B.1. of Chapter 5.

3 Aboveground magazines are all types of above grade (not earth-covered) magazines or storage pads.

4 Use this K-factor for NEW in PES up to 250,000 lb.

5 Use this K-factor for NEW in PES above 250,000 lb.

6 Modules and/or Cells are defined in subsection B.2. of Chapter 5.

Table 9-5. Intermagazine Hazard Factors and Distances
for Hazard Division 1.1
Part B - Distance in Feet (Sheet 1)

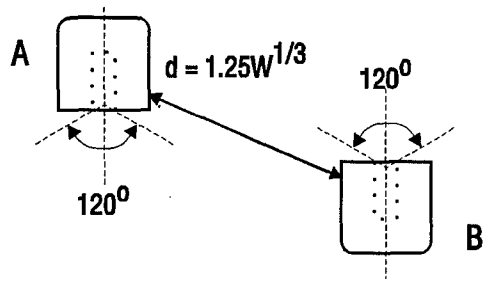
Net Expl.	Hazard Factor (K) from Part A									
Wt. (lb)	1.1	1.25	2	2.75	4	4.5	5	6	8	11
100	7	7	9	13	19	21	23	28	37	51
110	7	7	10	13	19	22	24	29	38	53
120	7	7	10	14	20	22	25	30	39	54
140	7	7	10	14	21	23	26	31	42	57
150	7	7	11	15	21	24	27	32	43	58
170	7	7	11	15	22	25	28	33	44	61
190	7	7	11	16	23	26	29	34	46	63
220	7	8	12	17	24	27	30	36	48	66
250	7	8	13	17	25	28	31	38	50	69
280	7	8	13	18	26	29	33	39	52	72
310	7	8	14	19	27	30	34	41	54	74
350	8	9	14	19	28	32	35	42	56	78
390	8	9	15	20	29	33	37	44	58	80
440	8	10	15	21	30	34	38	46	61	84
500	9	10	16	22	32	36	40	48	63	87
560	9	10	16	23	33	37	41	49	66	91
630	9	11	17	24	34	39	43	51	69	94
700	10	11	18	24	36	40	44	53	71	98
790	10	12	18	25	37	42	46	55	74	102
890	11	12	19	26	38	43	48	58	77	106
1000	11	13	20	28	40	45	50	60	80	110
1100	11	13	21	28	41	46	52	62	83	114
1200	12	13	21	29	43	48	53	64	85	117
1400	12	14	22	31	45	50	56	67	89	123
1500	13	14	23	31	46	52	57	69	92	126
1700	13	15	24	33	48	54	60	72	95	131
1900	14	15	25	34	50	56	62	74	99	136
2200	14	16	26	36	52	59	65	78	104	143
2500	15	17	27	37	54	61	68	81	109	149
2800	16	18	28	39	56	63	70	85	113	155
3100	16	18	29	40	58	66	73	87	117	160
3500	17	19	30	42	61	68	76	91	121	167
3900	17	20	31	43	63	71	79	94	126	173
4400	18	20	33	45	66	74	82	98	131	180
5000	19	21	34	47	68	77	85	103	137	188
5600	20	22	36	49	71	80	89	107	142	195
6300	20	23	37	51	74	83	92	111	148	203
7000	21	24	38	53	77	86	96	115	153	210
7900	22	25	40	55	80	90	100	119	159	219
8900	23	26	41	57	83	93	104	124	166	228
10000	24	27	43	59	86	97	108	129	172	237

Table 9-5. Intermagazine Hazard Factors and Distances
for Hazard Division 1.1
Part B - Distance in Feet (Sheet 2)

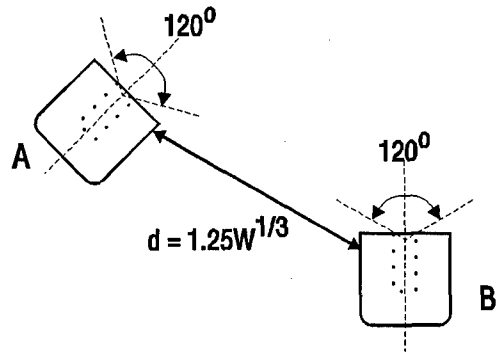
Net Expl. Wt. (lb)	Hazard Factor (K) from Part A									
	1.1	1.25	2	2.75	4	4.5	5	6	8	11
10000	24	27	43	59	86	97	108	129	172	237
11000	24	28	44	61	89	100	111	133	178	245
12000	25	29	46	63	92	103	114	137	183	252
14000	27	30	48	66	96	108	121	145	193	265
15000	27	31	49	68	99	111	123	148	197	271
17000	28	32	51	71	103	116	129	154	206	283
19000	29	33	53	73	107	120	133	160	213	294
22000	31	35	56	77	112	126	140	168	224	308
25000	32	37	58	80	117	132	146	175	234	322
28000	33	38	61	84	121	137	152	182	243	334
31000	35	39	63	86	126	141	157	188	251	346
35000	36	41	65	90	131	147	164	196	262	360
39000	37	42	68	93	136	153	170	203	271	373
44000	39	44	71	97	141	159	177	212	282	388
50000	41	46	74	101	147	166	184	221	295	405
56000	42	48	77	105	153	172	191	230	306	421
63000	44	50	80	109	159	179	199	239	318	438
70000	45	52	82	113	165	185	206	247	330	453
79000	47	54	86	118	172	193	215	257	343	472
89000	49	56	89	123	179	201	223	268	357	491
100000	51	58	93	128	186	209	232	278	371	511
110000	53	60	96	132	192	216	240	287	383	527
120000	54	62	99	136	197	222	247	296	395	543
140000	57	65	104	143	208	234	260	312	415	571
150000	58	66	106	146	213	239	266	319	425	584
170000	61	69	111	152	222	249	277	332	443	609
190000	63	72	115	158	230	259	287	345	460	632
220000	66	75	121	166	241	272	302	362	483	664
250000	69	79	126	173	252	283	315	378	504	693
280000	72	82	131	180	262	294	327	393	523	720
310000	74	85	135	186	271	305	338	406	541	744
350000	78	88	141	194	282	317	352	423	564	775
390000	80	91	146	201	292	329	365	438	584	804
440000	84	95	152	209	304	342	380	456	608	837
500000	87	99	159	218	317	357	397	476	635	873
560000	91	103	165	227	330	371	412	495	659	907
630000	94	107	171	236	343	386	429	514	686	943
700000	98	111	178	244	355	400	444	533	710	977
790000	102	116	185	254	370	416	462	555	740	1017
890000	106	120	192	265	385	433	481	577	770	1058
1000000	110	125	200	275	400	450	500	600	800	1100

Table 9-5. Intermagazine Hazard Factors and Distances
for Hazard Division 1.1
Part B - Distance in Feet (Sheet 3)

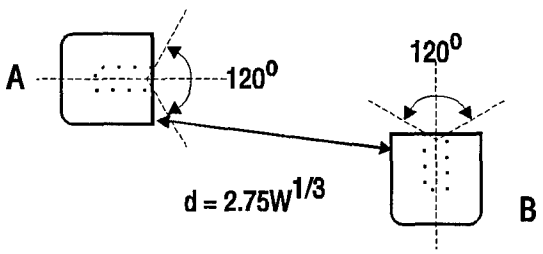
Net Expl. Wt. (lb)	Hazard Factor (K) from Part A									
	1.1	1.25	2	2.75	4	4.5	5	6	8	11
1000000	110	125	200	275	400	450	500	600	800	1100
1100000	114	129	206	284	413	465	516	619	826	1136
1200000	117	133	213	292	425	478	531	638	850	1169
1400000	123	140	224	308	447	503	559	671	895	1231
1500000	126	143	229	315	458	515	572	687	916	1259
1700000	131	149	239	328	477	537	597	716	955	1313
1900000	136	155	248	341	495	557	619	743	991	1362
2200000	143	163	260	358	520	585	650	780	1040	1431
2500000	149	170	271	373	543	611	679	814	1086	1493
2800000	155	176	282	388	564	634	705	846	1128	1550
3100000	160	182	292	401	583	656	729	875	1166	1604
3500000	167	190	304	418	607	683	759	911	1215	1670
3900000	173	197	315	433	630	708	787	944	1259	1731
4400000	180	205	328	451	655	737	819	983	1311	1803
5000000	188	214	342	470	684	769	855	1026	1368	1881
5600000	195	222	355	488	710	799	888	1065	1421	1953
6300000	203	231	369	508	739	831	923	1108	1478	2032
7000000	210	239	383	526	765	861	956	1148	1530	2104
7900000	219	249	398	548	797	896	996	1195	1593	2191
8900000	228	259	414	570	829	933	1036	1243	1658	2280
10000000	237	269	431	592	862	969	1077	1293	1724	2370
11000000	245	278	445	612	890	1001	1112	1334	1779	2446
12000000	252	286	458	630	916	1030	1145	1374	1832	2518
14000000	265	301	482	663	964	1085	1205	1446	1928	2651
15000000	271	308	493	678	986	1110	1233	1480	1973	2713



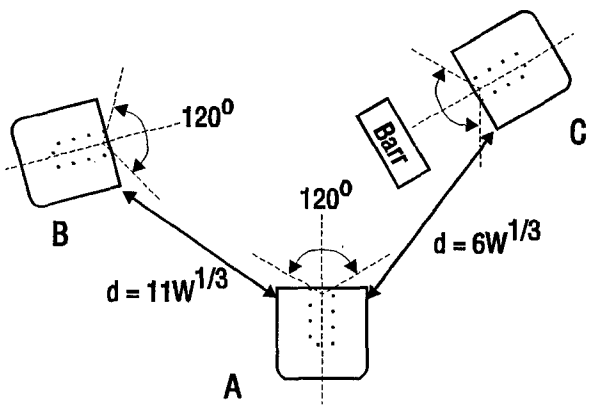
(a) Headwalls outside 120° sector



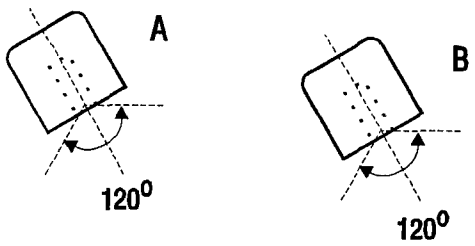
(b) Headwalls outside 120° sector



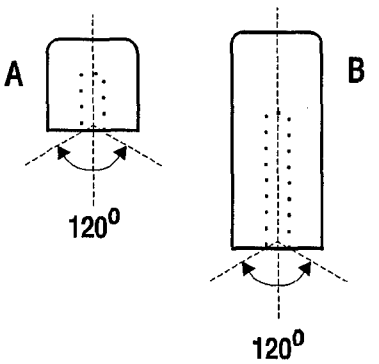
(c) One headwall inside 120° sector



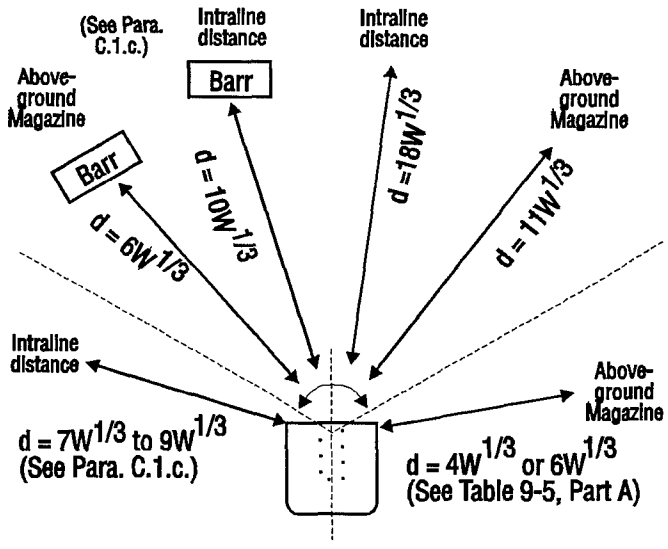
(d) Both headwalls inside 120° sector



(e) Canted igloos



(f) Igloos of significantly different length



(g) Barricaded & unbarricaded distances

Figure 9-1. Orientation Effects on Intermagazine Distance

2. **Hazard Division 1.2** (Tables 9-6 through 9-9)

a. Hazard Division 1.2 includes items configured for storage and transportation that do not mass detonate when a single item or package in a stack is initiated. Explosions involving the items result in their burning and exploding progressively, a few at a time, projecting fragments, firebrands, and unexploded items from the explosion site. Blast effects are limited to the immediate vicinity. Most projections for given items will fall inside one of the four specified inhabited building distances (400, 800, 1,200, and 1,800 feet) and items in this hazard division are thus categorized in Tables 9-6 through 9-9. However, inhabited building distance (IBD) requirements for Hazard Division 1.2 items may be specified in 100 foot increments with a 200 foot minimum distance based on approved alternate hazard classification test results for fragment hazards. In addition, Hazard Division 1.2 ammunition that does not exhibit any sympathetic detonation response in the stack test, or any detonation response in the external fire or bullet impact tests, or any reaction more severe than burning in the slow cook-off test, is termed unit risk Hazard Division 1.2 ammunition. The inhabited building distance for unit risk Hazard Division 1.2 ammunition is determined using the Hazard Division 1.1 fragment areal number density criteria applied to a single round of ammunition. Magazine earthcover and separate barricades generally are ineffective as a means for reducing these limiting ranges of protection. Earth-covered buildings may be used to their physical capacity for all items of this hazard division, provided they comply with the construction and siting requirements of Chapter 5 for Hazard Division 1.1 material. However, there is a 500,000 lb NEW storage limit for all aboveground storage structures for items of this hazard division with an IBD requirement greater than 800 ft.

b. Public traffic route distances give consideration to the transient nature of the exposure in the same manner as for Hazard Division 1.1. Public traffic route distance is computed as 60% of the IBD for items in this hazard division.

c. Intraline distances take into account the progressive nature of explosions involving these items (normally resulting from fire spread) and the ability to evacuate personnel from endangered areas before this progression involves large numbers of items. Exposed structures may be extensively damaged by projections and delayed propagation of explosion may occur due to ignition of combustibles by projections. Intraline distance is computed as 50% of the IBD for items of this hazard division. However, if the HE at an operating line PES is limited to 5,000 lb for items of this hazard division with an IBD requirement of 500 ft to 1,200 ft, then the intraline distance may be reduced to 200 ft.

d. Aboveground magazine distances provide a high degree of protection against any propagation of explosion. However, there is some risk of delayed propagation when the ES contains combustible dunnage or packing materials that may be ignited by projected firebrands. Items of this hazard division with IBD requirements of 1,200 ft or greater present a risk of propagation to adjacent aboveground magazines, particularly when packed in combustible containers. Storage in earth-covered magazines is therefore preferred. The aboveground magazine distance requirement is 50% of the IBD for items in this hazard division with IBD less than 400 ft; from 400 ft to 700 ft IBD, the aboveground magazine distance is 200 ft; and for IBD of 800 ft and greater, the aboveground magazine distance is 300 ft. Module storage requirements are provided in subsection B.2., Chapter 5.

3. **Hazard Division 1.3** (Table 9-10)

Hazard Division 1.3 includes items that burn vigorously with little or no possibility of extinguishment in storage situations. Explosions normally will be confined to pressure ruptures of containers and will not produce propagating shock waves or damaging blast overpressure beyond the magazine distance specified in Table 9-10. A severe hazard of spread of fire may result from tossing about of burning container materials, propellant, or other flaming debris.

4. **Hazard Division 1.4** (Table 9-11)

a. Hazard Division 1.4 items present a fire hazard with no blast hazard and virtually no fragmentation or toxic hazard beyond the fire hazard clearance ordinarily specified for high-risk materials. Separate facilities for storage and handling of these items shall be located not less than 100 feet from other than like facilities; except that, if both are of fire-resistive construction, they may be separated from one another by 50 feet.

b. Articles containing about 1 ounce or less of explosives and classified based on test results as 1.4S may be considered as inert for storage purposes and are not subject to 49 CFR 173 (reference (c)) for transport. Articles containing larger amounts of explosives, but also classified as 1.4S based upon tests may be considered inert for storage purposes but must be reviewed on an individual basis to determine if 49 CFR 173, (reference (c)) shall be applied for transport.

5. **Hazard Division 1.6** (Table 9-12)

Quantity-distance separations for Hazard Division 1.6 ammunition shall be based on the storage location and configuration. This information is detailed in Table 9-12 and footnotes thereto. A maximum of 500,000 NEW shall be permitted at any one location. Any special storage configuration and siting approved for Hazard Division 1.1 ammunition or explosives may be used for a storage of like explosive weights of Hazard Division 1.6 ammunition.

6. **Hazard Division 6.1**

a. Hazard Division 6.1 includes items that contain only toxic chemical or riot control agents. Items containing both explosives and toxic chemical or riot control agents may be included in Class 1, Divisions 1 through 4, based on testing in accordance with section G. of Chapter 3.

b. Hazard zones for toxic chemical agents are determined by the relative toxicity of the agents, the amount released to the atmosphere and the rate at which they are released (that is, evaporation, pressure, or explosive dispersal), terrain features, and meteorological conditions. Hazard zone calculations are based on maximum credible events (MCEs), using "Methodology for Chemical Hazard Prediction", (reference (o)).

c. Items containing both explosives and toxic chemical agents require application of both the appropriate Hazard Divisions 1.1 thru 1.4 Q-D and the class 6.1 hazard zone distance.

Table 9-6. Category (04), Hazard Division 1.2 Quantity-Distances. (See Note 1)

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft)	Magazine Distance (ft)	
				Above-ground	Earth-covered
No limit specifically required for safety reasons	400	240	200	200 (Note 2)	(Note 3)

Notes:

List of items (examples only): Small arms ammunition with explosive projectiles; 20mm ammunition with explosive projectiles; fuzed ammunition with non-explosive projectiles when caliber and packing limit the hazard in accordance with this hazard division; WP smoke hand grenades; and nonmass-detonating CBUs.[2]

1 Limited quantities of items in this hazard division, for reasons of operational necessity, may be stored in facilities such as hangars, troop buildings, and manufacturing or operating buildings without regard to quantity-distance. Examples of such items are small destructors, fuzes, firing devices, and 40mm grenades. Fragmentation shielding will be provided.

2 See subsection B.2. of Chapter 5, for module storage criteria.

3 Earth-covered buildings may be used to their physical capacity for this category of material provided they comply with the construction and siting requirements of Chapter 5 for Hazard Division 1.1 material.

Table 9-7. Category(08), Hazard Division 1.2 Quantity-Distances.

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft)	Magazine Distance (ft)	
				Above-ground	Earth-covered
No limit specifically required for safety reasons	800	480	400 (Note 1)	300 (Note 2)	(Note 3)

Notes:

List of items (examples only): Fixed and semifixed ammunition, rockets and rocket components, chemical ammunition containing explosive elements, and nonmass-detonating CBUs.[2]

1 If the HE in (08) 1.2 items at an operating line PES is limited to 5000 lbs, intraline distance may be reduced to 200 ft.

2 See subsection B.2. of Chapter 5, for module storage criteria.

3 Earth-covered buildings may be used to their physical capacity for this category of material provided they comply with the construction and siting requirements of Chapter 5 for Hazard Division 1.1 material.

Table 9-8. Category (12), Hazard Division 1.2[1] Quantity-Distances.

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft)	Magazine Distance (ft)	
				Above-ground	Earth-covered
500,000	1,200	720	600 (Note 2)	300 (Note 3)	(Note 4)

Notes:
List of items (examples only): Separate projectiles with explosive "D" filler, except high capacity types, caliber 8-inch or larger; fixed and semifixed ammunition; nonmass-detonating CBUs; rockets,rocket motors and nonmass-detonating rocket heads; and chemical ammunition containing explosive components

1 Items of this category present a risk of propagation to adjacent aboveground magazines, particularly when packed in combustible containers. Storage in earth-covered magazines is therefore preferred.
2 If the HE in (12) 1.2 items at an operating line PES is limited to 5000 lbs, intraline distance may be reduced to 200 ft.
3 See subsection B.2. of Chapter 5, for module storage criteria.
4 Earth-covered buildings may be used to their physical capacity for this category of material provided they comply with the construction and siting requirements of Chapter 5 for Hazard Division 1.1 material.

Table 9-9. Category (18), Hazard Division 1.2[1,2] Quantity-Distances.

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft)	Magazine Distance (ft)	
				Above-ground	Earth-covered
500,000	1,800	1,080	900	300	(Note 2)

Notes:
List of items (examples only): Nonmass-detonating HE-loaded projectiles, fixed and semifixed ammunition, and rockets and rocket heads.

1 Items of this category present a risk of propagation to adjacent aboveground magazines, particularly when packed in combustible containers. Storage in earth-covered magazines is therefore preferred.
2 Earth-covered buildings may be used to their physical capacity for this category of material provided they comply with the construction and siting requirements of Chapter 5 for Hazard Division 1.1 material.

Table 9-10. Hazard Division 1.3 Quantity-Distances. (Notes 1 and 2)

NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)	NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)	NEW (lbs)	IBD or PTR[3] (ft)	Above-ground IMD OR ILD[4] (ft)
1,000	75	50	92,000	296	196	560,000	627	413
2,000	86	57	94,000	297	197	570,000	632	415
3,000	96	63	96,000	298	198	580,000	636	418
4,000	106	69	98,000	299	199	590,000	641	420
5,000	115	75	100,000	300	200	600,000	645	422
6,000	123	81	110,000	307	205	610,000	649	424
7,000	130	86	120,000	315	210	620,000	654	426
8,000	137	91	130,000	322	215	630,000	658	428
9,000	144	96	140,000	330	220	640,000	662	430
10,000	150	100	150,000	337	225	650,000	667	432
12,000	159	105	160,000	345	230	660,000	671	435
14,000	168	111	170,000	352	235	670,000	675	437
16,000	176	116	180,000	360	240	680,000	679	439
18,000	183	120	190,000	367	245	690,000	684	441
20,000	190	125	200,000	375	250	700,000	688	443
22,000	195	130	210,000	383	255	710,000	692	445
24,000	201	134	220,000	390	260	720,000	696	447
26,000	206	138	230,000	398	265	730,000	700	449
28,000	210	142	240,000	405	270	740,000	704	451
30,000	215	145	250,000	413	275	750,000	708	453
32,000	219	147	260,000	420	280	760,000	712	455
34,000	224	149	270,000	428	285	770,000	716	457
36,000	228	151	280,000	435	290	780,000	720	459
38,000	231	153	290,000	443	295	790,000	724	461
40,000	235	155	300,000	450	300	800,000	728	463
42,000	238	157	310,000	458	305	810,000	732	465
44,000	242	159	320,000	465	310	820,000	735	467
46,000	245	161	330,000	473	315	830,000	739	469
48,000	247	163	340,000	480	320	840,000	743	471
50,000	250	165	350,000	488	325	850,000	747	472
52,000	252	167	360,000	495	330	860,000	750	474
54,000	254	169	370,000	503	335	870,000	754	476
56,000	256	171	380,000	510	340	880,000	758	478
58,000	258	173	390,000	518	345	890,000	761	480
60,000	260	175	400,000	525	350	900,000	765	482
62,000	262	177	410,000	533	355	910,000	769	484
64,000	264	180	420,000	541	361	920,000	772	486
66,000	266	182	430,000	549	366	930,000	776	487
68,000	268	183	440,000	556	371	940,000	779	489
70,000	270	185	450,000	564	376	950,000	783	491
72,000	272	186	460,000	571	381	960,000	786	493
74,000	274	187	470,000	579	386	970,000	790	495
76,000	276	188	480,000	586	391	980,000	793	496
78,000	278	189	490,000	593	395	990,000	797	498
80,000	280	190	500,000	600	400	1,000,000	800	500
82,000	284	191	510,000	605	402			
84,000	287	192	520,000	609	404			
86,000	290	193	530,000	614	407			
88,000	293	194	540,000	618	409			
90,000	295	195	550,000	623	411			

Notes for Table 9-10:

For quantities less than 1,000 lbs, the required distances are those specified for 1,000 lbs. The use of lesser distances may be approved when supported by test data and/or analysis.

Linear interpolation of NEW quantities between table entries is permitted.

For quantities above 1,000,000 lbs, the values given above will be extrapolated by means of cube-root scaling as follows:

For inhabited building distance (IBD) and public traffic route (PTR) distance, use $D = 8W^{1/3}$.

For aboveground intermagazine distance (IMD) and intraline distance (ILD), use $D = 5W^{1/3}$.

List of items (examples only): Military pyrotechnics; solid propellants in bulk, in containers, or in ammunition items; and nontoxic chemical ammunition.

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1 Items will be placed in this hazard division if they qualify for assignment to it after evaluation in accordance with Chapter 3.

2 For reasons of operational necessity, limited quantities of items in this hazard division, such as document destroyers, signaling devices, riot control munitions and the like, may be stored without regard to quantity-distance in accordance with fire protection regulations in facilities such as hangars, arms rooms, and manufacturing or operating buildings.

3 The same distances are used for IBD and PTR.

4 The same distances are used for aboveground IMD and ILD. Earth-covered buildings may be used to their physical capacity for this hazard division provided they comply with the construction and siting requirements of Chapter 5 and 9, respectively, for Hazard Division 1.1. Earth-covered magazines used to store only Hazard DIvision 1.3 items must be sited for a minimum of 100 lbs of Hazard DIvision 1.1 items using Tables 9-4 and 9-5.

Table 9-11. Hazard Division 1.4[1] Quantity-Distances.

NEW (lb)	Inhabited Building Distance (ft)	Public Traffic Route Distance (ft)	Intraline Distance (ft)	Magazine Distance (ft)	
				Aboveground	Earth-covered
Limited quantities[2]	.....	.....	.....	.....	.....
Larger quantities, no limit specifically required for safety reasons	100	100	50 (100 if combustible construction)	50 (100 if combustible construction)	No specified separation requirement

Notes:

List of items (examples only): Small arms ammunition without explosive projectiles, fuse lighters and squibs, distress signals, 20mm ammunition without explosive projectiles, colored smoke grenades,and explosive valves or switches (see subsection D.13. of Chapter 3).

1 With reasonable care in storage, Hazard Division 1.4 items may be stored in any weatherproof warehouse in a warehouse area for general supplies provided such warehouse is separated from all other warehouses by at least the aboveground magazine separation distance specified.

2 For reasons of operational necessity, limited quantities of items in this hazard division, such as small arms ammunition, riot control munitions, and so forth, may be stored without regard to quantity-distance in accordance with fire protection regulations in facilities such as hangars, arms rooms, and manufacturing or operating buildings. Also, small magazines for essentially the same usage may be separated by appropriate fire protection distances.

3 Magazines storing only Hazard Division 1.4 items may be located at 50 feet (100 feet, if combustible construction)from all other magazines or explosives operating locations regardless of the hazard division or quantity of explosives authorized in these adjacent structures. Because loss of the Hazard Division 1.4 stocks is understood in the event of an explosion of the adjacent structure, application of this provision must be accepted by the DoD Component on a case-by-case basis. Consideration shall be given to the quantities of Hazard Division 1.4 concerned.

Table 9-12. Quantity-Distance Criteria for Hazard Division 1.6 Ammunition.

NEW (lbs)	IBD or PTR (ft)	Aboveground IMD or ILD (ft)	NEW (lbs)	IBD or PTR (ft)	Aboveground IMD or ILD (ft)
100	37	23	75,000	337	211
200	47	29	80,000	345	215
300	54	33	85,000	352	220
400	59	37	90,000	359	224
500	64	40	95,000	365	228
600	67	42	100,000	371	232
700	71	44	110,000	383	240
800	74	46	120,000	395	247
900	77	48	125,000	400	250
1,000	80	50	130,000	405	253
2,000	101	63	140,000	415	260
3,000	115	72	150,000	425	266
4,000	127	79	160,000	434	271
5,000	137	86	170,000	443	277
6,000	145	91	175,000	447	280
7,000	153	96	180,000	452	282
8,000	160	100	190,000	460	287
9,000	166	104	200,000	468	292
10,000	172	108	225,000	487	304
15,000	197	123	250,000	504	315
20,000	217	136	275,000	520	325
25,000	234	146	300,000	536	334
30,000	249	155	325,000	550	344
35,000	262	164	350,000	564	352
40,000	274	171	375,000	577	361
45,000	285	178	400,000	589	368
50,000	295	184	425,000	601	376
55,000	304	190	450,000	613	383
60,000	313	196	475,000	624	390
65,000	322	201	500,000	635	397
70,000	330	206			

Notes for Table 9-12:

1 The same distances are used for aboveground intermagazine distances (IMD) and intraline distances (ILD). Earth-covered magazines may be used to their physical capacity for this hazard division, provided they comply with the construction and siting requirements of Chapters 5 and 9 for Hazard Division 1.1.

2 For quantities less than 100 lbs, the required distances are those specified for 100 lbs. The use of lesser distances may be approved when supported by test data and/or analysis.

3 Interpolation is permitted. For inhabited building distance (IBD) and public traffic route (PTR) use $D = 8W^{1/3}$. For aboveground IMD and intraline distance (ILD) use $5W^{1/3}$.

4 Unit risk distance for airblast applies as a minimum; that is, for IBD or PTR, $D = 40W^{1/3}$ and for aboveground IMD or ILD, $D = 18W^{1/3}$, based on a single round of ammunition.

5 For Hazard Division 1.6 items packed in non-flammable pallets or packing, stored in earth-covered steel or concrete arch magazines when acceptable to the DoD Component and the DDESB on a site-specific basis, the following quantity-distance criteria apply, unless Table 9-12 permits a lesser distance requirement; IBD and PTR -- 100 ft; aboveground IMD and ILD -- 50 ft; earth-covered IMD -- No specified requirement.

D. Airfields, heliports, and seadromes

1. Scope and application

a. This section applies to ammunition and explosives, which is under the control and custody of DoD personnel, at or near airfields, heliports, and seadromes which are located within the United States and U.S. territories and possessions. Chapter 10, section C., applies where these requirements cannot be met in a foreign nation. Its provisions do not apply to explosives items installed on aircraft or contained in survival and rescue kits such as flares, signals, egress system components, squibs, and detonators for jettisoning external stores, engine-starter cartridges, fire extinguisher cartridges, destructors in electronic equipment, explosives components of emergency equipment, and other such items or materials necessary for safe flight operations.

b. Combat aircraft loaded with the munitions, shown in subparagraphs D.1.b. (1), (2) and (3), below, are exempt from the intraline quantity-distance requirements to related facilities:

(1) Hazard Division (04) 1.2 - gun ammunition, 30 mm or less.

(2) Hazard Division 1.3 - tactical missiles or pyrotechnics.

(3) Hazard Division 1.4 - munition.

c. These Q-Ds shall be applied in conjunction with airfield clearance criteria as prescribed by DoD Components and Federal Aviation Regulations (reference (p)) as follows:

(1) For airfields, heliports, and seadromes used exclusively by DoD Components and allied nations military components, combat aircraft parking areas, ammunition and explosives cargo areas, alert hangars, and shelters may be located within the airfield clearance zone insofar as these Q-D standards are concerned, except in the explosives prohibited areas as described in subsection D.3., below.

(2) For airfields, heliports, and seadromes not used exclusively by DoD Components and allied nations military components, combat aircraft parking areas, ammunition and explosives cargo areas, alert hangars, and shelters shall be located as prescribed in Tables 9-13 and 9-14. (Refer to Table 9-14 first.)

2. **Measurement of separation distances**. In applying Tables 9-13 and 9-14, distances shall be measured as follows:

a. **Loaded aircraft to loaded aircraft**. Measure the shortest distance between explosives on one aircraft to explosives on the adjacent aircraft.

b. **Ammunition and explosives location to taxiways and runways**. Measure from the nearest point of the ammunition and explosives location to the nearest point of the taxiway and to the centerline of the runway.

Table 9-13. Hazard Division 1.1 - Quantity-Distance for Military Aircraft Parking Areas.

Net Expl. Wt. (lb)	Distance in ft for specific targets indicated in Table 9-14	Net Expl. Wt. (lb)	Distance in ft for specific targets indicated in Table 9-14
50	111	5,300	523
58	116	6,300	554
69	123	7,400	585
81	130	8,700	617
95	137	10,000	646
110	144	12,000	687
130	152	14,000	723
150	159	16,000	756
180	169	19,000	801
210	178	22,000	841
250	189	26,000	889
290	199	31,000	942
340	209	37,000	1,000
400	221	43,000	1,051
470	233	51,000	1,113
560	247	60,000	1,174
660	261	70,000	1,236
770	275	83,000	1,309
910	291	97,000	1,378
1,000	300	110,000	1,437
1,200	319	130,000	1,520
1,400	336	150,000	1,594
1,700	358	180,000	1,694
2,000	378	210,000	1,783
2,300	396	250,000	1,890
2,800	423	300,000	2,008
3,300	447	350,000	2,114
3,800	468	410,000	2,229
4,500	495	480,000	2,349
5,300	523	500,000	2,381

Notes:

1 To protect against low-angle, high-speed fragments, barricades should be provided; however, these distances will not be reduced.

2 The distance given for 0 to 50 pounds NEW constitutes the minimum spacing permitted.

3 The minimum distance for Hazard Division 1.1 of 1,250 feet (see Paragraph E.2.c. of Chapter 2) does not apply to targets for which this table is used.

Table 9-14. Application of Ammunition and Explosives Safety Distances (Airfields, Heliports, and Seadromes). Table entries refer to the key below.

To:	From:				
	Combat Aircraft Parking Area	Ammunition/ Explosives Cargo Area	Ammunition/ Explosives Storage Facility	Ammunition/ Explosives Operating Facility	Ready Ammunition Storage Facility
Combat Aircraft Parking Area	3a	3a	5	5	3a
Ammunition/Explosives Cargo Area	3a	3a	3	3	3a
Ammunition/Explosives Storage Facility	3	3	3	3	3
Ammunition/Explosives Operating Facility	4	4	4	4	4
Ready Ammunition Storage Facility	3	3	3	3	3
Inhabited Building	1	1	1	1	1
Public Traffic Route & Taxiway (joint DoD-Non-DoD use)	2	2	2	2	2
Runway (joint DoD-Non-DoD use)	1	1	1	1	1
Runway/Taxiway (DoD Component use only)	None	None	11	2	None
Aircraft Parking Area	10	10	6	6	10
Aircraft Passenger Loading/Unloading Area	7	7	7	7	7
Recreation Area	8	9	9	9	8

Key to Table 9-14:

1 Use appropriate inhabited building distance.

2 Use appropriate public traffic route distance.

3 For Hazard Division 1.1 explosives, use appropriate intermagazine distance. For Hazard Division 1.2, apply note 10, below.

3a For Hazard Division 1.1 explosives, use appropriate intermagazine distance. For Hazard Division 1.2, apply note 10, below. Protects against simultaneous detonation of ammunition on adjacent aircraft, but does not prevent serious damage to aircraft and possible propagation of detonation due to fragments, debris, or fire.

4 Use appropriate intraline distance.

5 Use Table 9-13 distances for mass-detonating items and appropriate public traffic route distances for nonmass-detonating items.

6 Use Table 9-13 distances for DoD Component aircraft parking areas, and appropriate inhabited building distance for non-DoD Component aircraft parking areas.

7 Use appropriate public traffic route distances for locations in the open where passengers enplane and deplane; use appropriate inhabited building distance if a structure is included where passengers assemble, such as a passenger terminal building.

Key to Table 9-14 (continued):

8 No distance required to recreational areas that are used exclusively for alert personnel manning the combat-loaded aircraft. Other recreational areas where people are in the open shall be at appropriate public traffic route distance. When structures, including bleacher stands, are a part of such area, appropriate inhabited building distance shall be used.

9 Recreational areas, where people are in the open, shall be at appropriate public traffic route distance. When structures, including bleacher stands are part of such area, appropriate inhabited building distance shall be used.

10 Within these areas of airfields, heliports, and seadromes exclusively used by DoD Components, the separation of aircraft parking areas from combat aircraft parking areas and their ready ammunition storage facilities and ammunition and explosives cargo areas are considered to be a command function. At joint DoD/non-DoD use airfields, heliports, and seadromes, the combat aircraft parking areas and its ready ammunition storage facilities and ammunition and explosives cargo area shall be separated from non-DoD aircraft as specified in item 6., above.

11 Use $18W^{1/3}$ distances from side or rear of standard earth-cover magazine containing mass-detonating items to taxiway; use appropriate public traffic route distance from side or rear of standard earth-covered magazine containing nonmass-detonating items to taxiway; use appropriate public traffic route distance from front of standard earth-covered magazines, and from any other storage location containing mass-detonating or nonmass-detonating items to runway.

3. **Ammunition and explosives prohibited areas.** All ammunition and explosives shall be prohibited in any area under approach and departure zones of all fixed and rotary wing aircraft landing facilities (DoD, other Federal, joint use and civil). The approach and departure zone surface or areas for aircraft are those so designated and described in detail for the various types of facilities in DoD Component airfield and airspace criteria directives. In general, the approach and departure zone begins near the end of a runway or landing area and extends outward to a given distance along, and symmetrically on each side of, the extended runway centerline or the aircraft approach axis of a heliport. Such zones flare uniformly from the landing area outward to a prescribed limit.

E. Pier and wharf facilities

1. **Applicability and scope.** This section applies to piers and wharf and associated facilities at which ammunition and explosives may be handled, or be present in ships' holds or service conveyances. Its provisions do not apply to ammunition or explosives stored in ships' magazines and intended for the service of shipboard armament or aircraft. However, they do apply to loading, off-loading, stowing, and shifting of such ammunition and explosives. Q-Ds herein are for Hazard Division 1.1. Effects of an explosion to be expected when these Q-Ds are applied are described in Chapter 2. If only ammunition and explosives of other hazard divisions are involved, the Q-Ds for such hazards shall be applied as appropriate.

2. **Determination of quantity of explosives in a ship**

a. On board ship, the various types of ammunition and explosives are stored relatively close to each other, and a detonation in the HE part of the cargo may receive considerable support from items that are normally considered to be only fragment or fire hazards; therefore, the total quantity of explosives on board a ship shall be determined in accordance with subsection B.1., above.

b. When ship units are separated by $11W^{1/3}$ distances or greater, Q-D will be based individually on the quantity of each ship unit. Lesser separation distances require that the explosives in both ship units be totalled for Q-D purposes.

3. **Measurement of separation distance**

a. **Ships at a Pier**. Measurement of separation distances between ships shall be from the nearest point of one unit to the nearest point of the other. Movement of railcars or trucks passing through the clear space is considered as an operational risk. It will generally be impracticable to separate berths at a single pier by enough distance to prevent mass detonation of ships containing complete cargoes of Hazard Division 1.1 ammunition. To the extent operationally feasible, therefore, scheduling shall be such as to reduce the number of such exposures and total time that they are required.

b. **Piers**. The separation distances between piers shall be measured from the nearest point of the ship unit at one pier to the nearest point of the ship unit under consideration at the other pier.

c. **Anchorages**. Measurements from anchorages generally shall be from the boundary of the area designated for the scuttling site or the explosives anchorage. In the case of the explosives anchorage, the separation distance to outside targets shall depend upon whether:

(1) The ship units that are loading or unloading within the explosives anchorage are separated properly, taking into consideration location and the amount of explosives in each ship unit. The ship unit equivalent for an explosives anchorage is a circle, the radius of which is the distance from the mooring buoy or the ship's anchor to the stern of the ship or of the ammunition lighters alongside when riding to the full scope of the chain. To maintain proper separation distance between loading or unloading ship units in the explosives anchorage, the ships shall moor or anchor so that at no time will they have a separation distance less than $11W^{1/3}$ if quantities are not to be totalled.

(2) The ships being loaded or unloaded at one area are separated properly from the loaded ships in another area and whether the loaded ships within the loaded ship area are separated properly from each other. If the latter conditions do not apply, the quantity for entering the table shall be the total quantity rather than the unit quantity.

d. **Dolphins or interrupted quays**. Measurement of separation distance between ships moored to dolphins or interrupted quays shall be from the nearest point of one unit to the nearest point of the other.

e. **Fixed targets**. The measurement of separation distance from moored ships to fixed targets on land shall be from the nearest boundary of the ship or barge unit to the nearest fixed target.

4. **Siting criteria and application of Q-D separation standards**

a. **Maritime prepositioning ships (MPS)**

(1) Reduced Q-D criteria may be applied to those MPS that contain up to 1,300,000 pounds NEW of ammunition stored in standard ISO shipping containers.

(2) Inhabited building and public traffic route Q-D arcs for applicable MPS can be determined using K = 40.85 with a 4,400 feet minimum fragment distance for inhabited building distance and K = 24.01 for public traffic route distance for MPS loads where no more than 52 percent of the NEW is Hazard Division 1.1 material. Above 52 percent, the K factor increases as shown in Table 9-15, Columns 2 and 3. Table 9-1 applies when the Hazard Division 1.1 material increases above 65 percent of the NEW.

(3) The Q-D arc between applicable MPS piers/anchorages and non-explosives loading piers/anchorages can be determined using K = 32 with a 3,500 feet minimum fragment distance for MPS loads where no more than 52 percent of the total NEW is Hazard Division 1.1 material. Above 52 percent, the K factor increases as shown in Table 9-15, Column 4. Table 9-16, Column 5 applies when the Hazard Division 1.1 material increases above 65 percent of the NEW.

Table 9-15. Variation of MPS Q-D Factors with Loadout.

Percent of Hazard Division 1.1	Inhabited Building Distance	Public Traffic Route	Ship-to-Ship
up to 52	40.85	24.01	32.00
53	40.97	24.08	32.10
54	41.10	24.16	32.19
55	41.22	24.23	32.29
56	41.35	24.30	32.39
57	41.47	24.37	32.48
58	41.59	24.44	32.58
59	41.71	24.52	32.67
60	41.83	24.59	32.77
61	41.95	24.66	32.86
62	42.07	24.73	32.95
63	42.19	24.80	33.05
64	42.30	24.86	33.14
65	42.42	24.93	33.23

b. **Scuttling site**

(1) A properly located scuttling site shall be provided, if practicable, for positioning a ship for its flooding or sinking in the event a vessel catches fire and must be moved to avert damage to other ships or piers. It shall have sufficient sea room and depth of water to permit the sinking of the largest vessel that may be handled at the installation so that the holds will be flooded completely at low water.

(2) Since an explosion may occur while the vessel is being moved, the location of the scuttling site shall provide the best available protection to other ships, piers, and shore installations.

(3) The location of the scuttling site will depend on the greatest net weight of mass-detonating explosives that may be in a single ship at any one time. The Q-D tables to be used will depend on the particular types of targets.

c. **Explosives anchorage**. The location of an explosives anchorage shall be separated not only from the main ship channel or from normally traversed routes of ships entering or leaving the harbor by column 9, Table 9-1 distances, but also by turning circles and stopping distances of the ships. Assuming that the diameter of the turning circle of a ship is 1,000 yards, an explosives anchorage shall be located so that a ship in the channel will clear an anchored explosives-laden ship. From the turning circle standpoint, the separation distance shall be not less than 3,000 feet. Occasional watercraft passing through the arcs, while outside both the main ship channel and normally traversed routes of ships entering and leaving the harbor, are not subject to Q-D requirements.

(1) **Separation of ships at explosives anchorages**

(a) When explosives anchorages are used for loading and unloading ships, as well as for fully loaded vessels anchored at their berths, ships that are being loaded or unloaded shall be separated from fully loaded ships.

(b) When the explosives anchorage is used only for loading and unloading ships, to prevent mass detonation, ships in the explosives anchorage shall be separated by at least $11W^{1/3}$ distances. Whenever possible, these separations distances shall be increased to $18W^{1/3}$ to reduce the loss potential of any incident.

(c) Loaded ships shall be separated one from another by at least $18W^{1/3}$ distances.

(2) **Separation of explosives anchorages from other targets**. Explosives anchorages shall be separated from explosives piers by $40W^{1/3}$ distances except when the anchorage is used only for the loading or unloading of vessels. In such cases, $18W^{1/3}$ distances may be used.

d. **Separation distances of ship units in tandem at the same pier**

(1) Since the second ship would be in an area of heavy fragment density from the exploding ship, it could be set afire and later caused to mass-detonate. A direct hit by a steel fragment on ammunition alongside the ship or in an open hold could also cause a mass-detonation. The separation distances based on blast damage alone, accordingly, are not enough to take care of such fragment hazards. Berthing of the two ships in tandem will help to decrease the fragment hazard to the explosives cargo of the second ship because of the additional protection afforded by the bow or stern.

(2) When two ships cannot be separated by $11W^{1/3}$ distances and are being loaded through all hatches, the spotting of railcars or trucks and the loading of hatches in both ships should be planned so as to put the greatest possible distance between open hatches of both ships, and between the trucks and railcars serving the two ships. When possible, the loading of the ships should be staggered.

e. **Separation of explosives ships from other ships**. Explosives ships being loaded or unloaded shall be separated from nonexplosives-carrying ships and from loaded explosives ships

that are not underway by $40W^{1/3}$ distances. Table 9-1, column 9, distances shall be used for protection of ships that are underway.

5. **Quantity-distance tables.** Figure 9-2 shall be used in applying Table 9-16 Q-D. Table 9-1 Q-D shall be maintained between explosives pier and wharf facilities and such ESs as administration and industrial areas, terminal boundaries, main ship channels, and public traffic routes. As an ES, ship or barge units must be separated from explosives operating and storage facilities (including holding yards) by Table 9-1, column 5, distances. As a PES, ship or barge units must be separated from explosives operating facilities by Table 9-16, column 2, (barricaded) distances, and column 3 (unbarricaded), distances, as appropriate.

6. **General cargo and vehicles at ammunition terminals.** Mission related general cargo, vehicles, and ammunition may be transferred through a terminal concurrently for the purpose of loading and/or offloading the same ship. Concurrent operations involving other ships shall be conducted at applicable quantity-distance separations. Separation of inert materials and equipment in holding areas shall be consistent with the requirements of Chapter 5, subsection E.5. Personnel entering the inert holding areas shall be limited both in number and time of exposure. Any labor intense activity shall take place at applicable quantity-distance separation.

Table 9-16. Quantity-Distance Separation for Pier and Wharf Facilities

Net Expl. Wt. (lb)	Distance in Feet Hazard Factor (K)			
	6	11	18	40
1,000	60	110	180	400
1,200	64	117	191	425
1,500	69	126	206	458
1,900	74	136	223	495
2,500	81	149	244	543
3,100	87	160	262	583
3,900	94	173	283	630
5,000	103	188	308	684
6,300	111	203	332	739
7,900	119	219	358	797
10,000	129	237	388	862
12,000	137	252	412	916
15,000	148	271	444	986
19,000	160	294	480	1,067
25,000	175	322	526	1,170
31,000	188	346	565	1,257
39,000	203	373	610	1,356
50,000	221	405	663	1,474
63,000	239	438	716	1,592
79,000	257	472	772	1,716
100,000	278	511	835	1,857
120,000	296	543	888	1,973
150,000	319	584	956	2,125
190,000	345	632	1,035	2,300
250,000	378	693	1,134	2,520
310,000	406	744	1,218	2,707
390,000	438	804	1,315	2,922
500,000	476	873	1,429	3,175
630,000	514	943	1,543	3,429
790,000	555	1,017	1,664	3,698
1,000,000	600	1,100	1,800	4,000
1,200,000	638	1,169	1,913	4,251
1,500,000	687	1,259	2,060	4,579
1,900,000	743	1,362	2,229	4,954
2,500,000	814	1,493	2,443	5,429
3,100,000	875	1,604	2,625	5,832
3,900,000	944	1,731	2,833	6,296
5,000,000	1,026	1,881	3,078	6,840
6,300,000	1,108	2,032	3,324	7,388
7,900,000	1,195	2,191	3,585	7,967
10,000,000	1,293	2,370	3,878	8,618
12,000,000	1,374	2,518	4,121	9,158
15,000,000	1,480	2,713	4,439	9,865

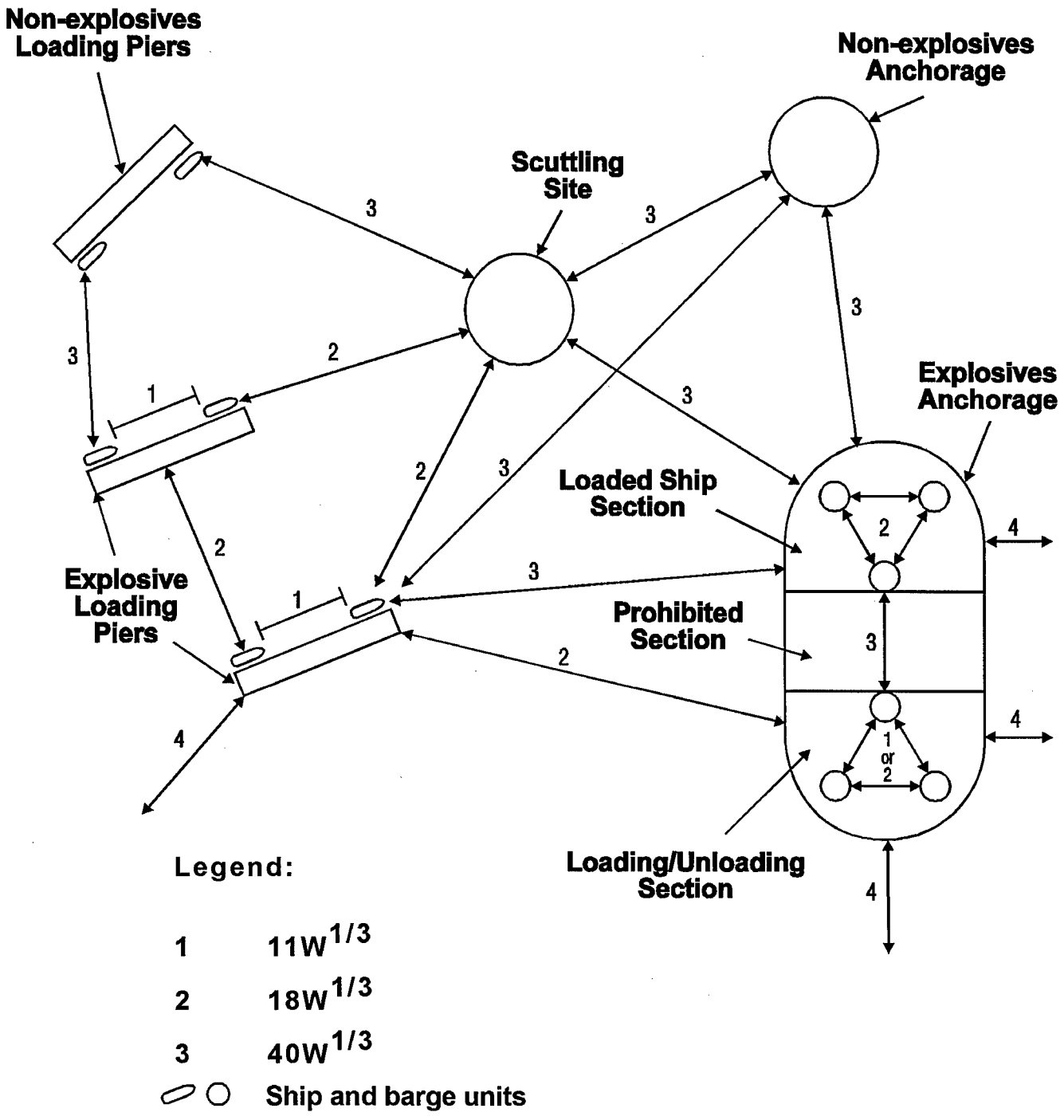


Figure 9-2. Application of Separation Distances for Ship and Barge Units.

F. Liquid propellants

1. Scope and application

a. This section applies to the storage of liquid propellants in all types of containers, including rocket and missile tankage. Quantities involving only one shipping container such as a 55-gallon drum or one 500-pound cylinder shall be stored and handled as prescribed by the controlling DoD Component.

b. **Exclusion**. Nothing in this section will govern the storage and handling of hydrocarbon fuels essential to the operation of ships, aircraft and vehicles. When hydrocarbons and other flammable liquids serve the dual purpose of both fuel and propellant, they will be stored as bulk fuels in accordance with applicable DoD Component directives. Hydrocarbons and other liquid fuels will be governed by this standard only when the fuel is actually charged into the missile, rocket, ammunition item or component thereof.

2. Concept

a. The DoD Component sponsoring the development of a liquid propellant, or first adopting for use any liquid propellant not listed in Table 9-17, shall be responsible for assigning the proper hazard classification and compatibility grouping, and for coordinating such assignment with other DoD Components.

b. These Q-D standards were developed on the premise that the controlling DoD Component will ensure that the materials of construction are compatible with the propellants, facilities are of appropriate design, fire protection and drainage control techniques are employed, and other specialized controls (such as nitrogen padding, blanketing, and tank cooling) are used when required.

c. When additional hazards associated with ammunition or explosives are involved, the safety distances prescribed in other sections of this Chapter shall be applied, as appropriate.

d. These standards are based upon the estimated credible damage resulting from an incident, without considering probabilities or frequency of occurrence.

3. Determination of propellant quantity

a. The total quantity of propellant in a tank, drum, cylinder, or other container shall be the net weight of the propellant contained therein. Where the storage containers are not separated one from the other by the appropriate distance or are not so subdivided as to prevent possible accumulative involvement, the quantity shall be considered as the total of all such storage containers. Quantity of propellant in the associated piping must be included to the points that positive means are provided for interrupting the flow through the pipe, or interrupting a reaction in the pipe in the event of an incident.

b. When incompatible propellants (see subsection F.9., below) are not separated by the required distances or provisions are not made to prevent their mixing, the combined quantity of the two shall be used. Consult Table 9-18 to determine if explosive equivalents apply.

c. When propellants (compatible or incompatible) at a specific location are subdivided so that the possibility of accumulative involvement is limited positively to the quantity of propellant

in any one of the divided segments, Q-D separation does not apply between such segments. However, the propellant content of the segment requiring the greatest distance shall be used to determine the separation to be maintained between the propellant location and other targets.

d. When the quantities of propellants are given in gallons, the conversion factors given in Table 9-19 may be used to determine the quantity in pounds.

4. **Measurement of separation distances**

a. Separation distances shall be measured from the closest hazard source (containers, buildings, segment, or positive cutoff point in piping, whichever is controlling).

b. When buildings containing a small number of cylinders or drums are present or when quantities of propellant are subdivided effectively, distances may be measured from the nearest container or controlling subdivision.

5. **Incompatible storage**. Separation distances between propellants of different CGs will be the inhabited building distance for the propellant quantity and the group that requires the greater distance. Consult Table 9-18 to determine if explosive equivalents apply and, if so, use distances found in Tables 9-1 or 9-3. Q-D standards for other conditions and explosive equivalents for any combination not contained in Table 9-18 shall be determined by the controlling DoD Component.

6. **Compatible storage**. Compatible storages of different propellants shall be separated by the intragroup storage distances required by the more hazardous groups.

7. **Hazard groupings**. Liquid propellants present various types and degrees of hazards. Based on these hazards, the following propellant groupings are established:

a. Group I comprises those assigned materials that are considered to be the least hazardous. They have a fire-hazard potential and require separation distances specified in paragraph F.9.a., below.

b. Group II comprises those assigned materials that are strong oxidizers. They exhibit properties such as vigorous oxidation or rapid combustion in contact with materials such as organic matter. Such contact may result in serious fires. These hazards necessitate use of the prescribed minimum spacing of storages and quantity limitations to restrict the loss of valuable property (see paragraph F.9.a., below).

c. Group III presents hazards primarily from the pressure rupture of the storage container resulting from fire, deflagration, or vapor phase explosions. Either pressure rupture of the container or vapor phase explosion can cause a fragment hazard from the container and its protective structure or other adjacent material. Separation distances for this hazard group are specified in paragraph F.9.a., below.

d. Group IV presents hazards that are the same as those of mass-detonating explosives. Incidents may create both blast overpressures and severe fragment hazards from the containers and surrounding equipment and material (see paragraph F.9.b., below).

8. **Specific hazardous locations**. Aside from the fact that the propellants differ from each other, as explained for the above groups, the predominant hazard of the individual propellant can vary depending upon the location of the propellant storage and the operations involved. In order of decreasing hazard, these conditions are:

a. **Range launch pads**. These involve research, development, testing, and space exploration launchings. Operations at these facilities are very hazardous because of the proximity of fuel and oxidizer to each other, the frequency of launchings, lack of restraint of the vehicle after liftoff, and the possibility of fallback with resultant dynamic mixing on impact. Launch vehicle tankage is involved here and explosive equivalents shall be used.

b. **Operational launch pads**. Activity here is similar to that at range launch pads except the frequency of firing is much less at the operational launch pads; the latter are defense- or combat-type operations and may well be one-time events. Launch vehicle tankage is involved and explosive equivalents must be used except as provided in paragraph F.8.e., below. When an operational pad is used for training launches, it shall be considered as a range launch pad.

c. **Static test stands**. Although these can involve experimental operations, the units remain static and are subject to better control than launch vehicles. Except when run tankage for fuel and oxidizer are mounted one above the other, it is possible to separate the tankage to reduce the hazard over that for the rocket or missile on the launch pad. Explosive equivalents shall be used except as provided in subsection F.5., above.

d. **Ready storage**. This storage is relatively close to the launch and static test stands; normally it is not involved directly in feeding the engine as in the case with run tankage, which is an integral part of all launch and test stand operations. The explosive equivalents shall be used if the facility design does not guarantee against fuel and oxidizer mixing and against detonation propagation to, or initiation at, the ready storage facility when a mishap occurs at the test stand, on the ground at the launch pad, or at the ready storage areas. Otherwise, fire and fragment hazards shall govern.

e. **Cold-flow test operations**. Fire and fragment hazards govern if the design is such that the system is closed except for approved venting, is completely airtight, fuel and oxidizer never are employed concurrently, and each has a completely separate isolated system and fitting types to preclude intermixing, and the propellants are of required purity. Otherwise, explosive equivalents shall be used.

f. **Bulk storage**. This is the most remote storage with respect to launch and test operations. It consists of the area, tanks, and other containers therein, used to hold propellant for supplying ready storage and, indirectly, run tankage where no ready storage is available. Fire and fragment hazards govern. If positive measures are not taken to prevent mixing of fuel and oxidizer or to prevent detonation propagation, the explosive equivalents shall be used.

g. **Rest storage**. This is temporary-type storage and most closely resembles bulk storage. It is a temporary parking location for barges, trailers, tank cars, and portable hold tanks used for topping operations when these units actually are not engaged in the operation; and for such vehicles when they are unable to empty their cargo promptly into the intended storage container. Fire and fragment hazards govern. The transporter becomes a part of that storage to which it is connected during propellant transfer.

h. **Run tankage (operating tankage)**. This consists of the tank and other containers and associated piping used to hold the propellants for direct feeding into the engine or device during operation. The contents of properly separated "run tanks" (operating tankage) and piping are normally considered on the basis of the pertinent hazards for the materials involved, except for

quantities of incompatible materials that are or can be in a position to become mixed. HE equivalents shall be used for quantities of such materials subject to mixing.

i. **Pipelines**. A 25-foot clear zone to inhabited buildings shall be maintained on each side of pipelines used for Group II or III propellants.

9. **Q-D standards**. The following standards are applicable to liquid propellants used for propulsion or operation of missiles, rockets, and other related devices:

a. **Hazard Groups I, II and III**. Table 9-20 applies. When Hazard Groups I, II or III materials are stored with more hazardous materials, under conditions prescribed in subsection F.8., above, Tables 9-1, 9-3, and 9-18 apply, as appropriate.

b. **Hazard Group IV**. Tables 9-1, 9-3, and 9-18 apply. Enter weight of explosive equivalent in Tables 9-1 or 9-3.

10. **Contaminated liquid propellants**

a. Caution shall be exercised in the storage and handling of contaminated liquid propellants. Such contamination may increase the degree of hazard associated with the propellant.

b. Liquid propellants known to be contaminated or in a suspect condition shall be isolated and provided separate storage from all other propellants pending laboratory analysis for verification of contamination and disposition requirements, if any.

Table 9-17. Liquid Propellant Hazard and Compatibility Groups.

Propellant	Hazard Group[1]	Storage Group[2]
Alcohols CH_3OH, C_2H_5OH, $(CH_3)_2CHOH$	I	C
Anhydrous Ammonia NH_3	I	C
Aniline $C_6H_5NH_2$	I	C
Hydrocarbon Fuels JP-4, JP-5, RP-1	I	C
Monopropellant NOS-58-6	I	C
Nitrogen Tetroxide N_2O_4	I	A
Otto Fuel II	I	G
Red Fuming Nitric Acid HNO_3	I	A
Bromine Pentafluoride BrF_5	II	A
Chlorine Trifluoride ClF_3	II	A
Hydrogen Peroxide Greater than 52% H_2O_2	II[3]	A
Liquid Fluorine LF_2	II	A
Liquid Oxygen LO_2	II	A
Perchloryl Fluoride CLO_3F	II	A
Oxygen Difluoride OF_2	II	A
Ozone Difluoride O_3F_2	II	A
Ethylene Oxide C_2H_4O	III	D
Hydrazine N_2H_4	III	C
Hydrazine-UDMH Mixtures	III	C
Liquid Hydrogen LH_2	III	C
Mixed Amine Fuels	III	C
Monomethylhydrazine CH_3NHNH_3	III	C
Pentaborane B_5H_9	III	D
Triethyl Boron B $(C_2H_5)_3$	I	D
UDMH $(CH_3)_2NNH_2$	III	C
Nitromethane CH_3NO_2	IV[5]	F[4]
Tetranitromethane $C(NO_2)_4$	IV	F

Notes for Table 9-17:

1 For some of the materials listed, the toxic hazard may be an overriding consideration. Consult applicable regulations and, if necessary, other authorities or publications for determination of toxic siting criteria.

2 All propellants in a compatibility group are considered compatible. Groupings are not to be confused with ammunition and explosives compatibility groupings with like letters.

3 Under certain conditions, this propellant can detonate. However, its sensitivity to detonation is not greater than that of a standard energetic double base solid propellant under the same conditions.

4 Nitromethane is chemically compatible with compatibility storage group C liquid propellants, but due to differences in hazards should be stored separately.

5 Technical grade nitromethane in unit quantities of 55 gallons or less in DOT 17E or C drums may be stored as Hazard Group II provided the following apply:

a. Drums are stored only one tier high.

b. Drums are protected from direct rays of sun.

c. Maximum storage life of 2 years, unless storage life tests indicate product continues to meet purchase specification. Such tests are to be repeated at 1 year intervals thereafter.

Table 9-18. Liquid Propellant Explosive Equivalents. (Notes 2, 3, 4, 5, 6, 7)

Propellant Combinations	Static Test Stands	Range Launch
LO_2/LH_2 or B_5H_9 + an oxidizer	60%	60%
LO_2/LH_2 + LO_2/RP-1	Sum of (60% for LO_2/LH_2)+ (10% for LO_2/RP-1)	Sum of (60% for LO_2/LH_2)+ (20% for LO_2/RP-1)
LO_2/RP-1 or LO_2/NH_3 or B_5H_9+ a fuel	10%	20% up to 500,000 pounds plus 10% over 500,000 pounds
IRFNA/Aniline (Note 1)	10%	10%
IRFNA/UDMH (Note 1)	10%	10%
IRFNA/UDMH + JP-4 (Note 1)	10%	10%
N_2O_4/UDMH + N_2H_4 (Note 1)	5%	10%
N_2O_4/UDMH + N_2H_4 (Note 1) + solid propellants	5% plus the explosive equivalent of the solid propellants.	10% plus the explosive equivalent of the sold propellant.
Tetranitromethane (alone or in combination)	100%	100%
Nitromethane (alone or in combination)	100%	100%

Notes for Table 9-18:

1 These are hypergolic combinations.

2 The percentage factors given in the table are to be used to determine equivalencies of propellant mixtures at static test stands and range launch pads when such propellants are located aboveground and are unconfined except for their tankage. Other configurations shall be considered on an individual basis to determine equivalencies.

3 The explosives equivalent weight calculated by the use of this table shall be added to any non-nuclear explosive weight aboard before distances can be determined from Tables 9-1 and 9-3.

4 These equivalencies apply also for the following substitutions:

a. Alcohols or other hydrocarbons for RP-1.

b. BrF_5, ClF_3, F_2, H_2, H_2O_2, OF_2, or O_2F_2 for LO_2.

c. MMH for N_2H_4 or UDMH.

d. C_2H_4O for any propellant.

e. NH_3 for any fuel resulting in a hypergolic combination.

5 Use LO_2/RP-1 distance for pentaborane plus a fuel and LO_2/LH_2 distances for pentaborane plus an oxidizer.

6 For quantities of propellant up to but not over the equivalent of 100 pounds of ex plosives, the distance shall be determined on an individual basis by the DoD Component. All personnel and facilities, whether involved in the operation or not, shall be protected by operating procedures, equipment design, shielding, barricading, or other suitable means.

7 Distance less than intraline are not specified. Where a number of prepackaged liquid propellant units are stored together, separation distance to other storage facilities shall be determined on an individual basis by the DoD Component, taking into consideration normal hazard classification procedures.

Table 9-19. Factors to be Used When Converting Gallons of Propellant into Pounds. (Note 1)

Item	Pounds per gallon	At Temperature °F
Anhydrous ammonia	5.1	68
Aniline	8.5	68
Bromine pentafluoride	20.7	68
Chlorine trifluoride	15.3	68
Ethyl alcohol	6.6	68
Ethylene oxide	7.3	68
Fluorine (liquid)	12.6	-306
Furfuryl alcohol	9.4	68
Hydrocarbon fuel JP-4	6.35	60
Hydrocarbon fuel JP-5	6.84	60
Hydrogen peroxide (90 percent)	11.6	68
Hydrazine	8.4	68
Isopropyl alcohol	6.6	68
Liquid hydrogen	0.59	-423
Liquid oxygen	9.5	-297
Methyl alcohol	6.6	68
Mono methyl hydrazine	7.3	68
Monopropellant NOS-58-6	9.46	68
Nitromethane	9.5	68
Nitrogen tetroxide	12.1	68
Otto fuel	10.5	77
Oxygen difluoride	12.7	-229
Ozone difluoride	14.6	-297
Pentaborane	5.2	68
Perchloryl fluoride	12.0	68
Red fuming nitric acid (IRFNA)	12.5	68
RP-1	6.8	68
Tetranitromethane	13.6	78
Triethyl Boron B	5.8	73
UDMH	6.6	68
UDMH/hydrazine	7.5	68

1 Conversion of quantities of propellant from gallons to pounds: Pounds of propellant = gallons X density of propellant in pounds per gallon.

Table 9-20. Quantity-Distance for Propellants.

Pounds of Propellant		Hazard Group I		Hazard Group II		Hazard Group III		
		IBD, PTR, & Incom-patible Group I [4]	Intra-group (ILD) [1] & Group I [5]	IBD, PTR, & Incom-patible Group II [6]	Intra-group (ILD) [1] & Group II [7]	IBD, PTR, & Incompatible Group III		Intra-group (ILD) [1] & Group III [11]
Over:	Not over:					Unpro-tected [9]	Protected [8, 10]	
0	100	30	25	60	30	600	80	30
100	200	35	30	75	35	600	100	35
200	300	40	35	85	40	600	110	40
300	400	45	35	90	45	600	120	45
400	500	50	40	100	50	600	130	50
500	600	50	40	100	50	600	135	50
600	700	55	40	105	55	600	140	55
700	800	55	45	110	55	600	145	55
800	900	60	45	115	60	600	150	60
900	1,000	60	45	120	60	600	150	60
1,000	2,000	65	50	130	65	600	175	65
2,000	3,000	70	55	145	70	600	190	70
3,000	4,000	75	55	150	75	600	200	75
4,000	5,000	80	60	160	80	600	210	80
5,000	6,000	80	60	165	80	600	220	80
6,000	7,000	85	65	170	85	600	225	85
7,000	8,000	85	65	175	85	600	230	85
8,000	9,000	90	70	175	90	600	235	90
9,000	10,000	90	70	180	90	600	240	90
10,000	15,000	95	75	195	95	1,200	260	95
15,000	20,000	100	80	205	100	1,200	275	100
20,000	25,000	105	80	215	105	1,200	285	105
25,000	30,000	110	85	220	110	1,200	295	110
30,000	35,000	110	85	225	110	1,200	300	110
35,000	40,000	115	85	230	115	1,200	310	115
40,000	45,000	120	90	235	120	1,200	315	120
45,000	50,000	120	90	240	120	1,200	320	120
50,000	60,000	125	95	250	125	1,200	320	125
60,000	70,000	130	95	255	130	1,200	340	130
70,000	80,000	130	100	260	130	1,200	350	130
80,000	90,000	135	100	265	135	1,200	360	135
90,000	100,000	135	105	270	135	1,200	365	135
100,000	125,000	140	110	285	140	1,800	380	140
125,000	150,000	145	110	295	145	1,800	395	145
150,000	175,000	150	115	305	150	1,800	405	150
175,000	200,000	155	115	310	155	1,800	415	155
200,000	250,000	160	120	320	160	1,800	425	160
250,000	300,000	165	125	330	165	1,800	440	165
300,000	350,000	170	130	340	170	1,800	455	170
350,000	400,000	175	130	350	175	1,800	465	175
400,000	450,000	180	135	355	180	1,800	475	180
450,000	500,000	180	135	360	180	1,800	485	180
500,000	600,000	185	140	375	185	1,800	500	185
600,000	700,000	190	145	385	190	1,800	515	190
700,000	800,000	195	150	395	195	1,800	530	195
800,000	900,000	200	150	405	200	1,800	540	200
900,000	1,000,000	205	155	410	205	1,800	550	205
[3] 1,000,000	2,000,000	235	175	470	235	1,800	630	235
2,000,000	3,000,000	255	190	505	255	1,800	675	255
3,000,000	4,000,000	265	200	535	265	1,800	710	265
4,000,000	5,000,000	275	210	555	275	1,800	740	275
5,000,000	6,000,000	285	215	570	285	1,800	760	285
6,000,000	7,000,000	295	220	585	295	1,800	780	295
7,000,000	8,000,000	300	225	600	300	1,800	800	300
8,000,000	9,000,000	305	230	610	305	1,800	815	305
9,000,000	10,000,000	310	235	620	310	1,800	830	310

Notes for Table 9-20:

1 See subsections F.5. and F.6.
2 See subsection F.1.
3 Extrapolations above 1,000,000 lbs extend well outside data included in the Bureau of Mines, Department of the Interior Report No. 5707, dated 1961, from which original Q-D tables were derived; however, they are supported by independent calculations and knowledge of like phenomena.
4 Values are one-half of the Group II inhabited building distance.
5 Values are three-fourths the Group II and Group III intragroup distances.
6 Distances were selected as three-fourths the Group III inhabited building distance and considered reasonable due to the lesser hazard.
7 Distances were derived from the Bureau of Mines, Department of the Interior Report No. 5707, dated 1961, modified and expanded. They average 37.5 percent of the inhabited building distances given in this report.
8 The term "protected" means that protection from fragments is provided by terrain, effective barricades, nets, or other physical means.
9 Distances are necessary to provide reasonable protection from fragments of tanks or equipment that are expected to be thrown in event of a vapor phase explosion.
10 Distances are the recommended inhabited building distances given in the Bureau of Mines, Department of the Interior Report No. 5707, dated 1961, and extrapolation thereof (2 cal/cm^2 on 1 percent water vapor curve).
11 Distances are an average of 37.5 percent of "protected" column.

G. Underground storage

1. Scope

a. This section details Q-D standards for the underground storage of military ammunition and explosives. Underground storage includes natural caverns and below grade, excavated chambers, but criteria of this section also apply to any storage facility providing the overpressure confinement effects typically encountered in underground storage. Use criteria of this section only when the minimum distance from the perimeter of a storage area to an exterior surface exceeds $0.25\ W^{1/3}$. Otherwise use aboveground siting criteria. This minimum distance most often, but not always, equals the thickness of the earth cover. This section addresses explosives safety criteria both with and without rupture of the earth cover.

b. Expected ground shock, debris, and airblast hazards from an accidental explosion in an underground storage facility depend on several variables, including the local geology and site specific parameters. These parameters vary significantly from facility to facility, so criteria listed here will likely be safety conservative for some geologies and configurations. Siting distances other than those listed may be used when validated by approved experimental or analytical results showing equivalent protection to that required. Default, approved methods for establishing Q-D are discussed below.

c. Q-D siting requirements of this section may be determined from the applicable equations or by interpolating between the table and figure entries.

d. The provisions of this section do not apply to storage in earth-covered magazines described in Chapter 5 of this Standard.

2. Design of underground storage facilities

a. Underground storage facilities may consist of a single chamber or a series of connected chambers. There may also be other protective construction features in the facility. The chamber(s) may be either excavated or natural geological cavities. Figure 9-3 illustrates general concepts for several possible configurations of underground facilities.

b. Design of new underground storage facilities must take into account site conditions, storage requirements and operational needs. Once these are established, a design may be developed based on Corps of Engineers definitive drawing number DEF 421-80-04.

c. An underground storage site normally requires designed protection against lightning only for exposed or partially exposed parts. Metal and structural parts of the site that have less than 2 feet (60 cm) of earth cover shall be protected as for an aboveground site (see Chapter 7). Lightning protection requirements must be considered on a site specific basis.

3. Explosion effects in underground storage sites

a. Confinement caused by the very limited space in underground storage will cause very high pressures of prolonged duration from an accidental explosion. Blast waves and dynamic flow fields will travel at high velocity throughout the underground facility. Ground shocks will be produced, and breakup of the earth cover with attendant debris throw may occur.

b. Under conditions of heavy confinement and high loading density Hazard Division 1.3 material may, while either detonating or burning, produce intense gas pressures sufficient to rupture the earth cover and create a significant debris hazard.

c. An accidental explosion involving only Hazard Division 1.2 material will likely start a fire that is sustained by burning packages and other ammunition. This may cause further explosions that become more frequent as the fires build and multiply until everything in the site is destroyed. Results of these repeated explosions will depend on the type and quantity of munitions, the type of explosion produced, and the layout of the facility. Hazards created outside the underground facility will likely not be as severe as those produced by Hazard Division 1.1 or 1.3 material.

4. **Protection provided**. Q-D criteria listed here provide separation distances from stored ammunition and explosives to mitigate the hazards caused by ground shock, debris, or air blast. The required distance for a given quantity and storage condition is that corresponding to the dominant (farthest-reaching) hazard that is applicable to the exposure under consideration. It is therefore the largest of the distances determined to be necessary for protection against the individual effects considered in turn.

5. **Chamber separation requirements**

a. Minimum storage chamber separation distances are required to prevent or control the communication of explosions or fires between donor and acceptor chambers. There are three modes by which an explosion or fire can be communicated: by rock spall, by propagation through cracks or fissures, and by airblast or thermal effects traveling through connecting passages.

b. **Prevention of damage by rock spall (Hazard Divisions 1.1 and 1.3)**. The chamber separation distance is the shortest distance (rock thickness) between two chambers. When an explosion occurs in a donor chamber, a shock wave is transmitted through the surrounding rock. The intensity of the shock decreases with distance. For small chamber separation distances, the shock may be strong enough to produce spalling of the rock walls of acceptor chambers. Spalled rock of sufficient mass, traveling with a sufficient velocity, may damage or sympathetically detonate impacted munitions in the acceptor chambers. When no specific protective construction is used, the minimum chamber separation distance, D_{cd} required to prevent hazardous spall effects is:

$$D_{cd} = 2.5 \bullet W^{1/3} \quad (9\text{-}1)$$

Where D_{cd} is in feet and W is in pounds. D_{cd}, in no case, shall be less than 15 feet.

The separation distances defined above applies to chamber loading densities up to 3.0 pounds per cubic foot, as determined from Table 9-21 and moderate to strong rock types. This loading density is the basis for values of D_{cd} listed in Table 9-22. For greater loading densities in moderate to strong rock, the required separation distance is:

$$D_{cd} = 5.0 \bullet W^{1/3} \quad (9\text{-}2)$$

For weak rock, at all loading densities, the separation distance is:

$$D_{cd} = 3.5 \bullet W^{1/3} \quad (9\text{-}3)$$

c. **Prevention of propagation by rock spall (Hazard Divisions 1.1 and 1.3).** If damage to stored munitions in the adjacent chambers is acceptable, the chamber separation distance can be reduced to the distance required to prevent propagation of the detonation by the impact of rock spall against the munitions. This is considered an immediate mode of propagation because time separations between donor and acceptor explosions may not be sufficient to prevent coalescence of blastwaves. Unless analyses or experiments indicate otherwise, explosives weights subject to this mode must be added to other donor explosives weights to determine NEW. When no special protective construction is used, the separation distance, D_{cp}, to prevent explosion communication by spalled rock is:

$$D_{cp} = 1.5 \bullet W^{1/3} \tag{9-4}$$

Where D_{cp} is in feet and W is in pounds.

When the acceptor chamber has protective construction to prevent spall and collapse (into the acceptor chamber) the separation distance to prevent propagation by impact of spalled rock is:

$$D_{cp} = 0.75 \bullet W^{1/3} \tag{9-5}$$

D_{cp} is in feet and W is the weight in pounds of Hazard Divisions 1.1 and 1.3 material in the donor chamber. Separation distances, D_{cp} and D_{cd}, are listed in Table 9-22. These distances are based on an explosive loading density of about 17 lb/ft^3. The distances will likely be safety conservative for lower loading densities but the effects have not been quantified.

d. **Prevention of propagation through cracks and fissures (Hazard Divisions 1.1 and 1.3).** Propagation between a donor and acceptor chamber has been observed to occur when natural, near horizontal jointing planes, cracks or fissures in the rock between the chambers are opened by the lifting force of the detonation pressure in the donor chamber. Prior to construction of a multi-chamber magazine, a careful site investigation must be made to ensure that such joints or fissures do not extend from one chamber location to an adjacent one. Should such defects be encountered during facility excavation, a reevaluation of the intended siting will be required.

e. **Prevention of propagation through passageways (Hazard Divisions 1.1 and 1.3).** Flame and hot gas may cause delayed propagation. Time separations between the original donor event and the potential explosions of this mode will likely be sufficient to prevent coalescence of blastwaves. Consequently, for purposes of Q-D siting, only the maximum credible explosives weight need be used to determine NEW. In order to protect assets, blast and fire resistant doors must be installed within multi-chambered facilities. Evaluations for required chamber separations due to this communication mode should be made on a site specific basis using procedures outlined in Corps of Engineers definitive drawing DEF 421-80-04.

f. For Hazard Divisions 1.1 and 1.3 materials, chamber entrances at the ground surface, or entrances to branch tunnels off the same side of a main passageway, shall be separated by at least 15 feet (5 meters). Entrances to branch tunnels off opposite sides of a main passageway shall be separated by at least twice the width of the main passageway.

g. Chambers, containing only Hazard Divisions 1.2 and 1.4 material and separated by the appropriate distance listed above, may be used to the limits of their physical capacities except for any items having special stacking and NEW restrictions. However, when Hazard Division 1.2 or

1.4 material is stored in the same chamber with Hazard Division 1.1 or 1.3 material, the propellant and explosive content of all hazard divisions material shall be added to obtain NEW.

6. **Critical chamber cover thickness**. The chamber cover thickness is the shortest distance between the natural rock surface at the chamber ceiling (or in some cases, a chamber wall) and the ground surface. The critical cover thickness required to prevent breaching of the chamber cover by a detonation is $2.5W^{1/3}$ for all types of rock.

7. **External Q-D determinations**

a. **Hazard division material dependence**

(1) **Hazard Division 1.1 and 1.3 materials**. Distances shall be determined from the total quantity of explosives, propellants, pyrotechnics, and incendiary materials in the individual chambers, unless the total quantity is subdivided to prevent rapid communication of an incident from one subdivision to another (see subsection B.2., above). All Hazard Divisions 1.1 and/or 1.3 material subject to involvement in a single incident shall be assumed to contribute to the explosion yield as would an equal weight of TNT. Any significant and validated differences in energy release per unit mass of the compositions involved from that of TNT may be considered. A connected chamber or cavern storage site containing Hazard Division 1.1 or 1.3 material shall be treated as a single chamber site, unless explosion communication is prevented by adequate subdivision or chamber separation.

(2) **Hazard Division 1.2 materials**. Except for primary fragments from openings to underground storage, external explosives safety hazards are not normally significant for Hazard Division 1.2 materials. The safe distance for both IBD and PTR is the IBD distance in Tables 9-6 through 9-9 for locations within ±10 degrees of the centerline of a tunnel opening. These default criteria apply only to those detonations which occur where a line-of-sight path exists from the detonation point to any portion of the tunnel opening. For detonations which do not have a line-of-sight path to the tunnel opening, or where the line-of-sight path is intercepted by a barricade beyond the opening, the IBD and PTR hazard distances are zero.

(3) **Hazard Division 1.4 materials**. External explosives safety hazards are not normally significant for Hazard Division 1.4 materials. Accordingly, external Q-D criteria do not apply for Hazard Division 1.4 materials.

b. **Q-D reference points**

(1) Distances determined by blast or debris issuing from tunnel openings shall be the minimum distance measured from the openings to the nearest wall or point of the location to be protected. Use extended centerlines of the openings as reference lines for directional effects.

(2) Distances determined for airblast and debris produced by breaching of the chamber cover shall be the minimum distance from an exterior point defined by chamber cover thickness, on the ground surface above the storage chamber to the nearest wall or point of the location to be protected. For configurations where the storage chambers are not distinct from the access tunnel, the distance is the shortest distance from the tunnel roof directly above the charge to the surface.

(3) Distances determined for ground shock shall be the minimum distance measured from the nearest wall of the storage chamber to the location to be protected.

c. **Inhabited building distance (Hazard Divisions 1.1 and 1.3 materials).** Inhabited building distances shall be the largest of those distances required for protection against ground shock, debris, and airblast as defined below.

(1) **Ground shock**

(a) For protection of residential buildings against significant structural damage by ground shock, the maximum particle velocity induced in the ground at the building site may not exceed the following values, which form the basis for the equations in subparagraph G.5.c. (1)(b), below:

2.4 ips in soil,

4.5 ips in weak rock, and

9.0 ips in strong rock.

(b) For sitings in moderately strong to strong rock with chamber loading densities of 3.0 lbs/ft^3 (50 kg/m^3) or less, the IBD for ground shock, D_{ig} is:

$$D_{ig} = 5.8 \bullet W^{1/3} \quad (9\text{-}6a)$$

Where D_{ig} is in feet and W is the explosive quantity in pounds.

For higher loading densities in chambers sited in moderately strong to strong rock, and for all loading densities in other materials, the IBD for ground shock is:

$$D_{ig} = 12.5 \bullet f_g \bullet W^{4/9} \text{ (Moderately strong to strong rock)} \quad (9\text{-}6b)$$

$$D_{ig} = 11.1 \bullet f_g \bullet W^{4/9} \text{ (Weak rock)} \quad (9\text{-}6c)$$

$$D_{ig} = 2.1 \bullet f_g \bullet W^{4/9} \text{ (Soil)} \quad (9\text{-}6d)$$

Values of D_{ig}/f_g are shown in Table 9-23. The dimensionless, decoupling factor, f_g depends on chamber loading density, w, and is:

$$f_g = (4/15) \bullet w^{0.3}. \quad (9\text{-}7)$$

Values of f_g are shown in Table 9-24. Chamber loading density is the NEW (in pounds) divided by the volume of the storage chamber, V_c (in cubic feet). Alternate values for D_{ig} may be used only when justified by site specific ground shock data.

(2) **Debris**

(a) A minimum IBD distance of 1800 feet (550 meters) for debris throw from an opening shall apply within ±10 degrees to either side of the centerline axis of that opening unless positive means are used to prevent or control the debris throw.

(b) Distances required for protection of inhabited areas against the effects of debris D_{id} thrown from breaching of the cover material over a detonation depend on the thickness of the cover, C, over the storage chamber. Siting criteria for debris from a surface breach need not be considered for chamber cover thicknesses greater than the critical value, C_c, of $2.5W^{1/3}$. If the cover thickness is less than C_c, the distance, D_{id}, will be calculated from $D_{id} = f_d \bullet f_c \bullet W^{0.41}$, where $f_d = 0.6 \bullet W^{0.18}$, and f_c is a constant related to the type of rock around the storage chamber.

(c) Values of D_{id}/f_d, for hard (moderately strong to strong) rock and for weak rock, are listed in Tables 9-25 and 9-26, respectively. Values of f_c are shown graphically in Figure 9-4. Values for the decoupling factors f_g and f_d are listed in Table 9-24.

(d) Special features may be incorporated in the design of underground facilities to reduce the IBD for debris ejected through tunnel openings.

1 Debris traps are pockets excavated in the rock at or beyond the end of sections of tunnel, designed to catch debris from a storage chamber detonation. Debris traps should be at least 20 percent wider and 10 percent taller than the tunnel leading to the trap, with a depth (measured along the shortest wall) of at least one tunnel diameter.

2 Expansion chambers are very effective in entrapping debris, as long as the tunnels entering and exiting the chambers are either offset in axial alignment by at least two tunnel widths, or enter and exit the chambers in directions that differ by at least 45 degrees.

3 Portal barricades provide a means of reducing IBD from debris by obstructing the path of the debris as it exits the tunnel. Construction and location requirements for barricades are contained in subsection C.5., Chapter 5.

4 High-pressure closures are large blocks constructed of concrete or other materials, that can obstruct or greatly reduce the flow of blast effects and debris from an explosion, from or into a storage chamber. For chamber loading densities of about 0.625 lb/ft^3 or above, closure blocks will contain 40 percent or more of the explosion debris within the detonation chamber, provided that the block is designed to remain intact. If a closure block fails under the blast load, it will produce a volume of debris in addition to that from the chamber itself. However, since the block's mass and inertia are sufficient to greatly reduce the velocity of the primary debris, the effectiveness of other debris-mitigating features, such as debris traps, expansion chambers, and barricades is increased.

(e) Debris traps, and expansion chambers intended to entrap debris, must be designed to contain the full potential volume of debris, based on the maximum capacity of the largest storage chamber. Design specifications for debris traps, expansion chambers, closure blocks and portal barricades are given in Corps of Engineers definitive drawing number DEF 421-80-04.

(f) Use of barricades in conjunction with any other of these features will lower the debris hazard to a level where Q-D considerations for debris will not be required.

(3) **Airblast**

(a) An explosion in an underground storage chamber may produce external airblast from two sources; the exit of blast from existing openings (tunnel entrances, ventilation shafts, etc.) and the rupture or breach of the chamber cover by the detonation. Required inhabited building distances are to be independently determined for each of these airblast sources, with the maximum IBD used for siting. If the chamber cover thickness is less than the critical thickness, C_c, given in subsection G.6., above, some amount of external airblast will be produced, depending on the cover thickness. Use the following procedure to find IBD for airblast produced by breaching of the chamber cover:

$C \leq 0.25W^{1/3}$: Use IBD for surface burst of bare explosives charge (Table 9-1, Note 3)

$0.25W^{1/3} < C \leq 0.50W^{1/3}$: Use 1/2 of IBD for surface burst of bare explosives charge

$0.50W^{1/3} < C \leq 0.75W^{1/3}$: Use 1/4 of IBD for surface burst of bare explosives charge

$0.75W^{1/3} < C$: Airblast hazards from blast through the earth cover are negligible relative to ground shock or debris hazards.

(b) Overpressure and debris hazards must be determined for each facility opening whose cross-section area is five percent or more of that of the largest opening.

(c) Distance vs overpressure along the centerline axis of a single opening is:

$$R = 149.3 \bullet D_{HYD} \bullet [(W/V_E)^{0.5}/p_{SO}]^{1/1.4} \quad (9\text{-}8a)$$

where:

R: distance from opening (feet),

D_{HYD}: effective hydraulic diameter that controls dynamic flow issuing from the opening (feet) [Compute D, using the minimum, cross-sectional area of the tunnel that is located within five tunnel diameters of the opening, as D = 4•A/P, where A is the area and P is the perimeter],

P_{SO}: overpressure at distance R (psi).

W: maximum credible event (MCE) in pounds

V_E: Total volume engulfed by the blast wavefront within the tunnel system at the time the wavefront arrives at the point of interest (ft^3)

(d) Distance vs overpressure off the centerline axis of the opening is:

$$R(\theta) = R(\theta=0)/(1 + (\theta/56)^2)^{1/1.4} \quad (9\text{-}8b)$$

where:

$R(\theta = 0)$ is the distance along the centerline axis, and

θ is the horizontal angle from the centerline (degrees).

(e) Equations 9-8a and 9-8b show that the distance providing protection from an overpressure exceeding P_{SO} depends on the hydraulic diameter, and the angle from the centerline axis for the location of interest. Figure 9-5 shows the ratio of off-axis to on-axis distances.

(f) Find required IBD distances for airblast using the appropriate equations discussed above, with the criteria that the total incident overpressure at IBD shall not exceed:

$P_{SO} = 1.2$ psi for $W < 100{,}000$ lbs, (9-9a)

$P_{SO} = 44.57 \bullet W^{-0.314}$ psi for $100{,}000 \leq W \leq 250{,}000$ lbs, (9-9b)

PSO = 0.9 psi for $W > 250{,}000$ lbs. (9-9c)

(g) For the overpressures of Equations 9-9a to 9-9c, on-axis IBD distances are:

$R = 131.1 \bullet D_{HYD} \bullet (W/V_E)^{1/2.8}$ for $W < 100{,}000$ lbs, (9-10a)

$R = 9.91 \bullet D_{HYD} \bullet W^{0.581}/V_E^{0.357}$ for $100{,}000 \ W \leq 250{,}000$ lbs, (9-10b)

$$R = 161.0 \bullet D_{HYD} \bullet (W/V_E)^{1/2.8} \text{ for } W > 250{,}000 \text{ lbs,} \quad (9\text{-}10c)$$

(h) Q-D distances for IBD for airblast may be determined from the equations listed above or from entries in Tables 9-27 and 9-28.

(4) **Airblast mitigation methods for reducing IBD**. Special features that may be incorporated in underground storage facilities to reduce the airblast IBD include:

(a) **Facility layouts**. A single-chamber facility with a straight access tunnel leading from the chamber to the portal is commonly called a "shotgun" magazine because the blast and debris are channeled to the external area as if fired from a long-barreled gun. More complex facility layouts will provide some reductions in the exit pressures due to reflections of the explosive shock against the tunnel walls. The cumulative effect is to reduce the overpressure at the shock front to the point that the peak overpressure is produced by the detonation gas flow following the front. The detonation gas pressure decreases as the volume it occupies increases. Therefore, the peak overpressure produced at the tunnel opening will also decrease with an increase in the total volume of the tunnels and chambers that can be filled by the blast as it travels from the detonation source (e.g., a storage chamber) to the opening, as given in the previous section. Larger facilities will, therefore, produce greater reductions in the effective overpressure at the opening, which will, in turn, reduce the IBD. The IBD should be reduced by 10 percent when two or more openings of similar cross-sectional area exist.

(b) **Expansion chambers**. Expansion chambers are so-named because of the volume they provide for the expansion of the detonation gasses behind the shock front as it enters the chamber from a connecting tunnel. Some additional degradation of the peak pressure at the shock front occurs as the front expands into the chamber and reflects from the walls. The principal benefit provided by an expansion chamber, however, is simply the added volume which decreases pressures. Expansion chambers also have practical purposes. They may be used as loading/unloading chambers, providing weather protection for the transfer of munitions from trucks to materials handling equipment prior to placement in storage chambers, or as turn-around areas for transport vehicles servicing facilities through a single entry passage.

(c) **Constrictions**. Constrictions are short lengths of tunnel whose cross sectional areas are reduced to one-half or less of the normal tunnel cross section. The use of constrictions should be limited to locations within 5 tunnel diameters of the tunnel exit or to the entrances of storage chambers. A constriction near the tunnel exit, where the overpressure has dropped near a minimum value in the tunnel, defines the hydraulic diameter to be used in Equation 9-8a. The purpose of a constriction at a chamber entrance is to reduce the intrusion of airblast and thermal effects into the chamber from a detonation in an adjacent chamber. A constricted chamber entrance also reduces the area, and hence the total loading on a blast door installed to protect the chamber contents.

(d) **Portal barricades**. For most underground storage facilities, the airblast from a storage chamber detonation that exits a tunnel portal will be in the form of a shock wave. It will expand in all directions from the portal in a manner similar to that from a detonation at the portal. A barricade in front of the portal will reflect that portion of the shock wave moving directly outward from the portal. By reflecting this portion of the total airblast, the pressures along the extended tunnel axis are reduced, and the pressures in the opposite direction, behind the portal are increased. The result is a more circular IBD area centered at the portal. Since much of the blast

is also reflected upward, the total IBD area is less than would occur without a barricade. For cases where the blast must travel a large distance from the storage chamber to the portal, with several changes in direction along the travel path, the airblast exiting the portal may primarily consist of a strong, highly-directional gas flow. A barricade will intercept such a flow and deflect it in directions 90 degrees from the tunnel axis. Whether the blast exiting the portal is shock or gas flow-dominated, the barricade must be located within certain minimum and maximum standoff distances to be effective. For the barricade design recommended in subsection C.5., Chapter 5, these limits are one to three tunnel diameters (at the portal). Portal barricades reduce the IBD along the extended tunnel axis by 50 percent. The total IBD area is only slightly reduced, but will change to a circular area, half of which is behind the portal. The barricade should be constructed as described in subsection C.5., Chapter 5 and Corps of Engineers definitive drawing number DEF 421-80-04.

(e) **High-pressure closures**

1 High Pressure Closures are large blocks constructed of concrete or other materials, that can obstruct or greatly reduce the flow of blast effects and debris from an explosion, from or into a storage chamber. If used to provide complete protection to the contents of a chamber from an explosion in another chamber, the block must be designed to move from a normally-closed position to an open position to allow entry into the chamber. Blast doors are not required for this type of closure block. If used to reduce Q-D by restricting the blast outflow from a chamber, the block must be designed to be rapidly driven from an open to a closed position by the detonation pressures in the chamber. While this type of block will provide some protection of chamber contents from an explosion in another chamber, blast doors must also be used to provide complete protection. Tests have shown that a closure block with sufficient mass can obstruct the initial outflow of airblast from an explosion in a chamber to reduce pressures in the connecting tunnels by a factor of two or more, even when the block is destroyed. Blocks with sufficient strength to remain structurally intact can provide greater reductions. Since many variables influence the performance of a closing device, their design details must be developed on a site-specific basis.

2 A 50% reduction in IBD should be applied to a high pressure closure block provided that the block is designed to remain intact in the event of an explosion. This reduction is applicable for loading densities of 0.625 lb/ft^3 or higher. For loading densities lower than 0.625 lb/ft^3 (but greater than 0.0625 lb/ft^3), reductions may be calculated by the formula:

$$y(\%) = 50 \bullet \log_{10}(16.02 \bullet w) \qquad (9\text{-}11)$$

where y is the percent reduction in IBD, and w is loading density in lb/ft^3. For loading densities lower than 0.0625 lb/ft^3; $y(\%) = 0$.

Closure block design criteria are found in Corps of Engineers definitive design drawing number DEF 421-80-04.

d. **Public traffic route (PTR) distance (Hazard Divisions 1.1 and 1.3 materials)**

(1) **Ground Shock**. Q-D is 60 percent of IBD for ground shock.

(2) **Debris**. Q-D is 60 percent of IBD for debris.

(3) **Airblast**. Q-D is 60 percent of IBD for airblast.

e. **Intraline distance (Hazard Divisions 1.1 and 1.3 materials)**

(1) **Ground shock**. Q-D criteria for ground shock do not apply.

(2) **Debris**. For locations within ±10 degrees of the centerline of a tunnel opening, site intraline facilities at IBD for debris issuing from the opening, calculated as directed in subparagraph G.7.c.(2), above. Q-D criteria for debris are not applicable for locations greater than ±10 degrees from the centerline axis of an opening.

(3) **Airblast**. Overpressure at barricaded and unbarricaded intraline distances shall not exceed 12 and 3.5 psi, respectively.

f. **Distance to aboveground magazines (Hazard Divisions 1.1 and 1.3 materials)**

(1) **Ground shock**. Q-D criteria for ground shock do not apply.

(2) **Debris**. For locations within ±10 degrees of the centerline of an opening, site aboveground magazines at IBD, for that debris issuing from the opening, in accordance with subparagraph G.7.c.(2), above. Q-D criteria for debris from rupture of the chamber cover do not apply.

(3) **Airblast**. Overpressure at barricaded and unbarricaded aboveground magazine distance shall not exceed 27 and 8 psi, respectively.

g. **Distance to earth-covered aboveground magazines (Hazard Divisions 1.1 and 1.3 materials)**

(1) **Ground Shock**. Q-D criteria for ground shock do not apply.

(2) **Debris**. Q-D criteria for debris from rupture of the chamber cover do not apply. Q-D criteria for debris issuing from an opening do not apply if the magazine is oriented for side-on or rear-on exposures to the debris but the criteria do apply for frontal exposures. Site earth-covered magazines that are located within ±10 degrees of the centerline of an opening and oriented for a frontal debris exposure at IBD for that debris hazard calculated as directed in subparagraph G.7.c.(2), above.

(3) **Airblast**. These sitings are based on the strength of the earth-covered magazines (ECM) under consideration and utilize side-on overpressures calculated from Equations 9-8a and 9-8b.

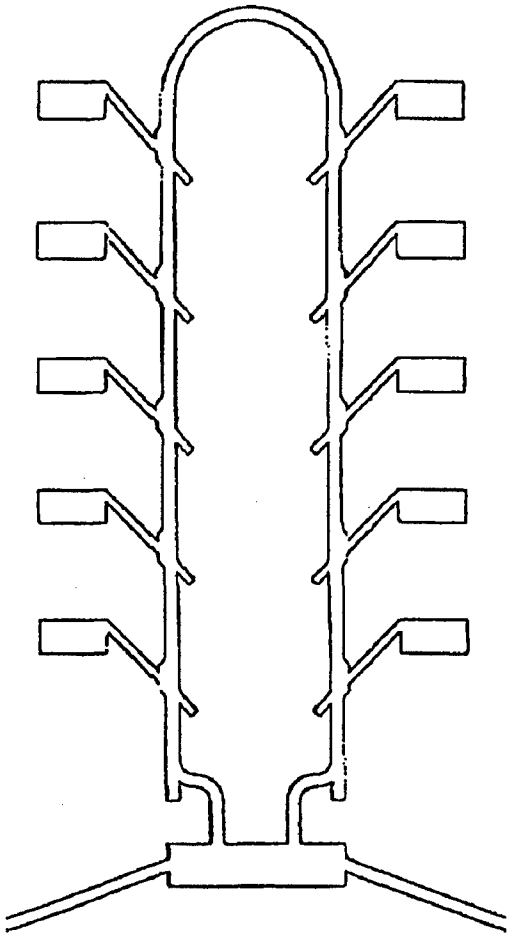
(a) **Head-on exposure**

1 7-Bar ECM: Site where the side-on overpressure, p_{SO}, is 29 psi.

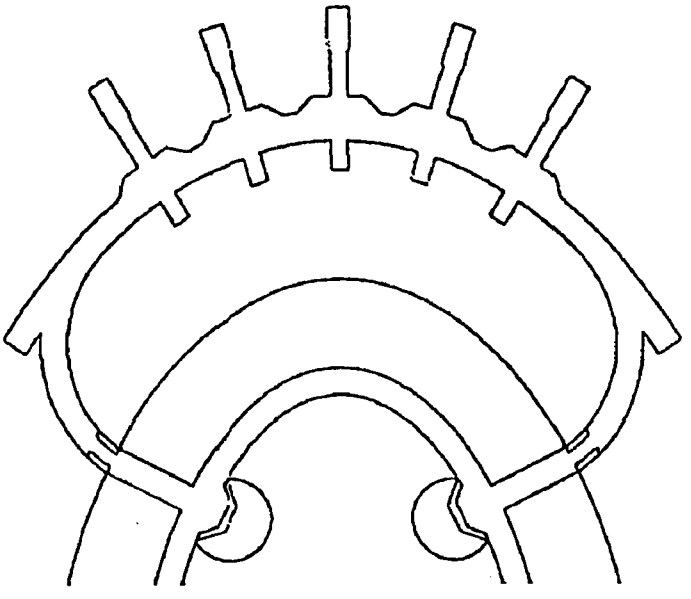
2 3-Bar ECM: Site where the side-on overpressure, p_{SO}, is 16 psi.

3 Undefined ECM: Site where the side-on overpressure, p_{SO}, is 3.5 psi.

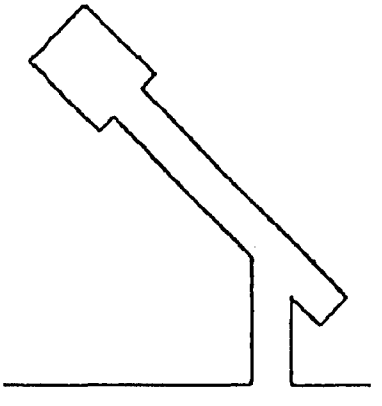
(b) **Other than head-on exposure**. Site all ECMs where side-on overpressure, p_{SO}, is 45 psi.



(a) Large Facility
20,000 to 200,000 kg (NEW) per chamber



(b) Medium Facility
2,000 to 20,000 kg (NEW) per chamber



(c) Small Facility
2,000 kg (NEW) per chamber or less

Figure 9-3. Typical Underground Facilities.

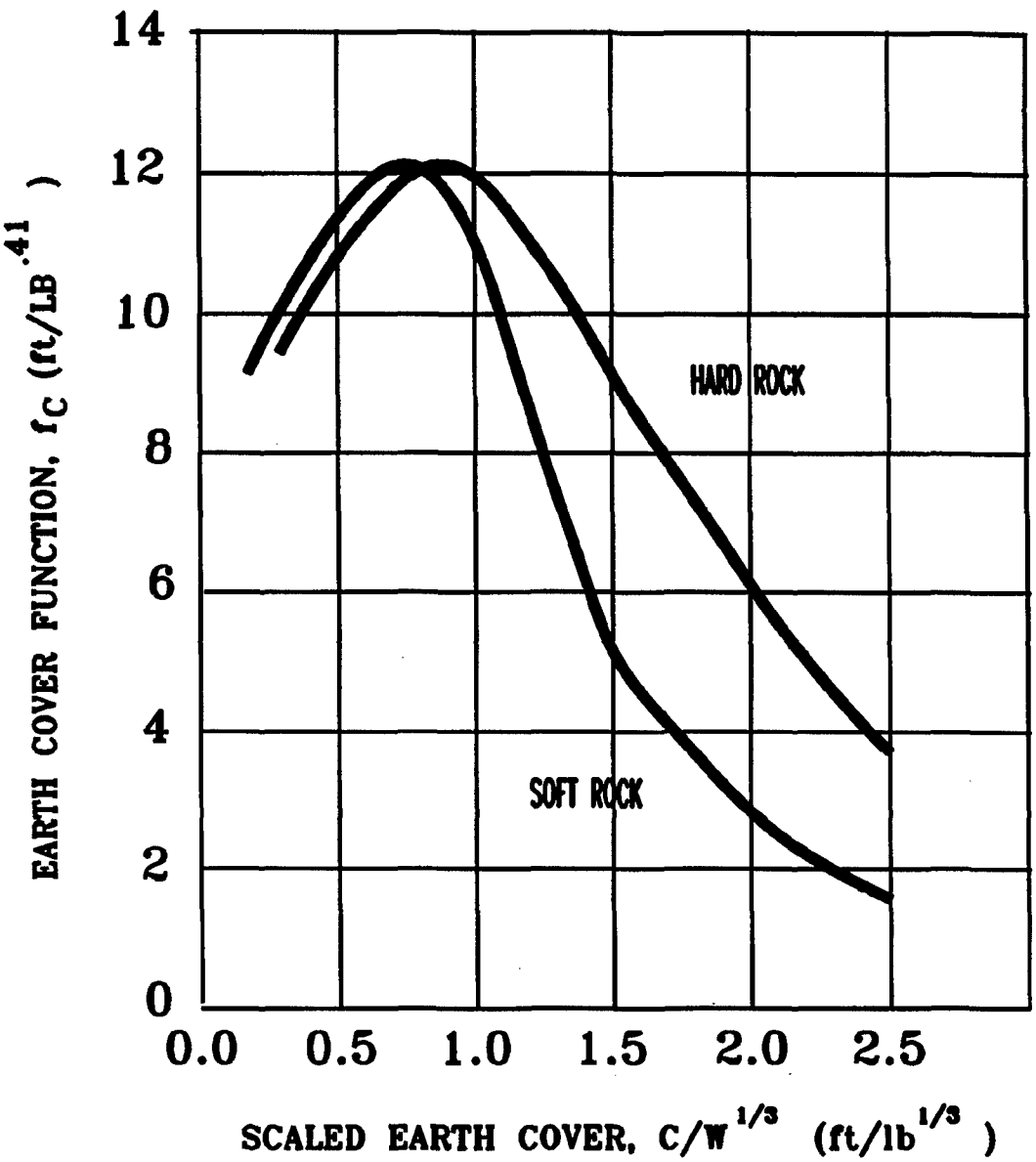


Figure 9-4. Debris Dispersal Functions

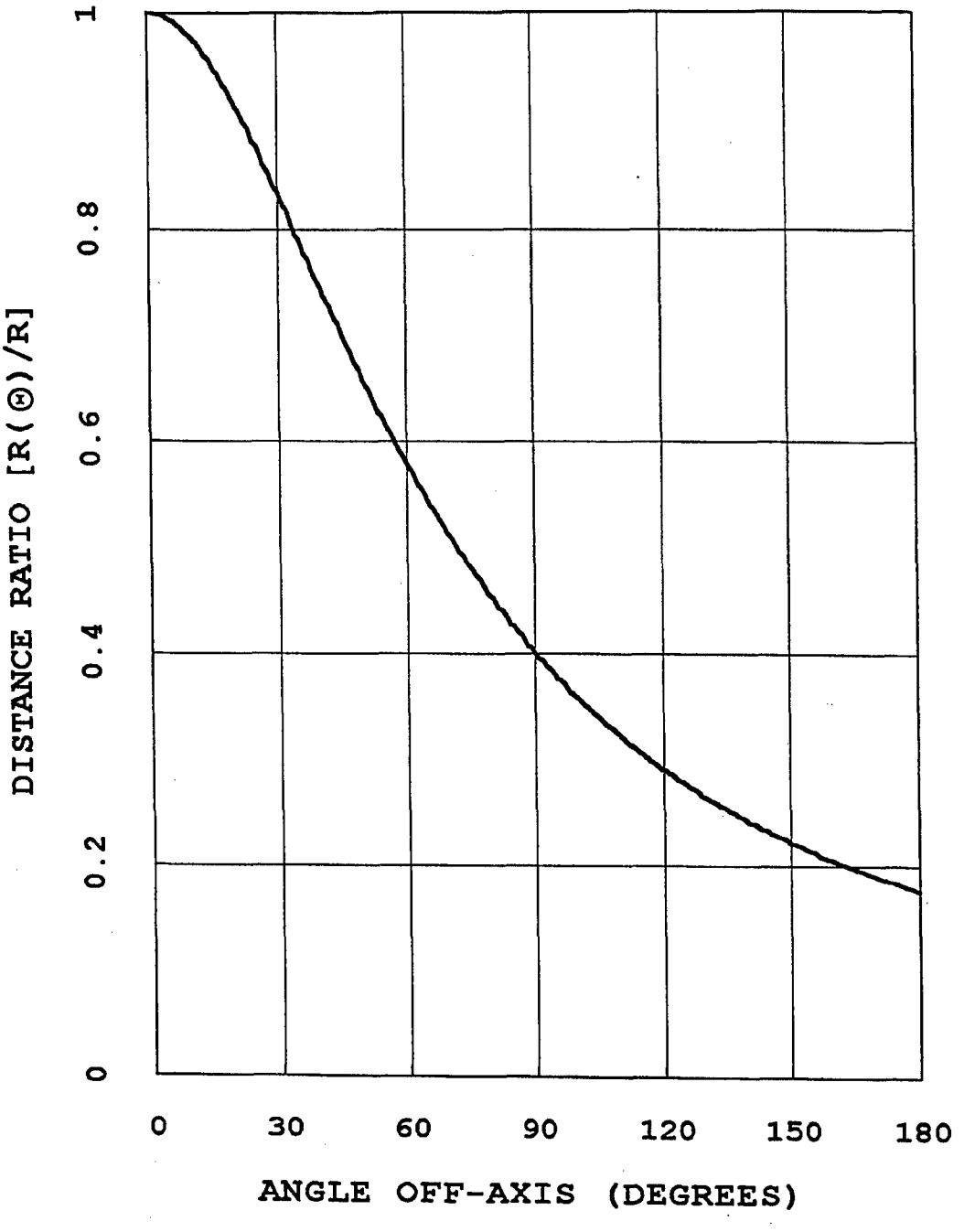


Figure 9-5. Constant Pressure Contour.

Table 9-21. Chamber Loading Density (w).

NEW (lbs)	Chamber Volume (ft^3)							
	2,000	5,000	10,000	20,000	30,000	50,000	75,000	100,000
1,000	0.500	0.200	0.100	0.050	0.033	0.020	0.013	0.010
1,200	0.600	0.240	0.120	0.060	0.040	0.024	0.016	0.012
1,400	0.700	0.280	0.140	0.070	0.047	0.028	0.019	0.014
1,600	0.800	0.320	0.160	0.080	0.053	0.032	0.021	0.016
1,800	0.900	0.360	0.180	0.090	0.060	0.036	0.024	0.018
2,000	1.000	0.400	0.200	0.100	0.067	0.040	0.027	0.020
2,500	1.250	0.500	0.250	0.125	0.083	0.050	0.033	0.025
3,000	1.500	0.600	0.300	0.150	0.100	0.060	0.040	0.030
3,500	1.750	0.700	0.350	0.175	0.117	0.070	0.047	0.035
4,000	2.000	0.800	0.400	0.200	0.133	0.080	0.053	0.040
5,000	2.500	1.000	0.500	0.250	0.167	0.100	0.067	0.050
6,000	3.000	1.200	0.600	0.300	0.200	0.120	0.080	0.060
7,000	3.500	1.400	0.700	0.350	0.233	0.140	0.093	0.070
8,000	4.000	1.600	0.800	0.400	0.267	0.160	0.107	0.080
9,000	4.500	1.800	0.900	0.450	0.300	0.180	0.120	0.090
10,000	5.000	2.000	1.000	0.500	0.333	0.200	0.133	0.100
12,000	6.000	2.400	1.200	0.600	0.400	0.240	0.160	0.120
14,000	7.000	2.800	1.400	0.700	0.467	0.280	0.187	0.140
16,000	8.000	3.200	1.600	0.800	0.533	0.320	0.213	0.160
18,000	9.000	3.600	1.800	0.900	0.600	0.360	0.240	0.180
20,000	10.000	4.000	2.000	1.000	0.667	0.400	0.267	0.200
25,000	12.500	5.000	2.500	1.250	0.833	0.500	0.333	0.250
30,000	15.000	6.000	3.000	1.500	1.000	0.600	0.400	0.300
35,000	17.500	7.000	3.500	1.750	1.167	0.700	0.467	0.350
40,000	20.000	8.000	4.000	2.000	1.333	0.800	0.533	0.400
45,000	22.500	9.000	4.500	2.250	1.500	0.900	0.600	0.450
50,000	25.000	10.000	5.000	2.500	1.667	1.000	0.667	0.500
60,000	30.000	12.000	6.000	3.000	2.000	1.200	0.800	0.600
70,000	35.000	14.000	7.000	3.500	2.333	1.400	0.933	0.700
80,000	40.000	16.000	8.000	4.000	2.667	1.600	1.067	0.800
90,000	45.000	18.000	9.000	4.500	3.000	1.800	1.200	0.900
100,000	50.000	20.000	10.000	5.000	3.333	2.000	1.333	1.000
120,000	60.000	24.000	12.000	6.000	4.000	2.400	1.600	1.200
140,000	70.000	28.000	14.000	7.000	4.667	2.800	1.867	1.400
160,000	80.000	32.000	16.000	8.000	5.333	3.200	2.133	1.600
180,000	90.000	36.000	18.000	9.000	6.000	3.600	2.400	1.800
200,000	100.000	40.000	20.000	10.000	6.667	4.000	2.667	2.000
300,000	150.000	60.000	30.000	15.000	10.000	6.000	4.000	3.000
400,000	200.000	80.000	40.000	20.000	13.333	8.000	5.333	4.000
500,000	250.000	100.000	50.000	25.000	16.667	10.000	6.667	5.000
600,000	300.000	120.000	60.000	30.000	20.000	12.000	8.000	6.000
700,000	350.000	140.000	70.000	35.000	23.333	14.000	9.333	7.000
800,000	400.000	160.000	80.000	40.000	26.667	16.000	10.667	8.000
900,000	450.000	180.000	90.000	45.000	30.000	18.000	12.000	9.000
1,000,000	500.000	200.000	100.000	50.000	33.333	20.000	13.333	10.000

Table 9-22. Chamber Separation.

Weight (lbs)	D_{cp} (ft)	D_{cd} (ft)		
	$1.5W^{1/3}$	$2.5W^{1/3}$	$3.5W^{1/3}$	$5.0W^{1/3}$
1,000	15	25	35	50
1,200	16	27	37	53
1,400	17	28	39	56
1,600	17.5	29	41	58
1,800	18	30	43	61
2,000	19	31	44	63
2,500	20.4	34	48	68
3,000	22	36	50	72
3,500	23	38	53	76
4,000	24	40	56	79
4,500	25	41	58	83
5,000	26	43	60	85
6,000	27	45	64	91
7,000	29	48	67	96
8,000	30	50	70	100
9,000	31	52	73	104
19,000	40	67	93	133
12,000	34	57	80	114
14,000	36	60	84	121
16,000	38	63	88	126
18,000	39	66	92	131
20,000	41	68	95	136
25,000	44	73	102	146
30,000	47	78	109	155
35,000	49	82	114	164
40,000	51	85	120	171
45,000	53	89	124	178
50,000	55	92	129	184
60,000	59	98	137	196
70,000	62	103	144	206
80,000	65	108	151	215
90,000	67	112	157	224
100,000	70	116	162	232
120,000	74	123	173	247
140,000	78	130	182	260
160,000	81	136	190	271
180,000	85	141	198	282
200,000	88	146	205	292
250,000	94	157	220	315
300,000	100	167	234	335
350,000	106	176	247	352
400,000	111	184	258	368
450,000	115	192	268	383
500,000	119	198	278	397
600,000	127	211	295	422
700,000	133	222	311	444
800,000	139	232	325	464
900,000	145	241	338	483
1,000,00	150	250	350	500

Table 9-23. Distances to Protect Against Ground Shock.

Weight(lbs)	$2.1W^{4/9}$	D_{ig}/f_g $11.1W^{4/9}$	$12.5W^{4/9}$	D_{ig} $5.8W^{1/3}$
1,000	45	239	269	58
1,200	49	259	292	62
1,400	53	278	313	65
1,600	56	295	332	68
1,800	59	311	350	71
2,000	62	325	366	73
2,500	68	359	405	79
3,000	74	390	439	84
3,500	79	417	470	88
4,000	84	443	499	92
4,500	88	467	525	96
5,000	93	489	551	99
6,000	100	530	597	105
7,000	107	568	640	111
8,000	114	603	679	116
9,000	120	635	715	121
10,000	126	665	749	125
12,000	137	722	813	133
14,000	146	773	870	140
16,000	155	820	923	146
18,000	163	864	973	152
20,000	171	906	1,020	157
25,000	189	1,000	1,126	170
30,000	205	1,084	1,221	180
35,000	220	1,161	1,308	190
40,000	233	1,232	1,388	198
45,000	246	1,298	1,462	206
50,000	257	1,361	1,532	214
60,000	279	1,476	1,662	227
70,000	299	1,580	1,779	239
80,000	317	1,677	1,888	250
90,000	334	1,767	1,990	260
100,000	350	1,852	2,085	269
120,000	380	2,008	2,261	286
140,000	407	2,150	2,421	301
160,000	432	2,282	2,570	315
180,000	455	2,404	2,708	327
200,000	477	2,520	2,837	339
250,000	526	2,782	3,133	365
300,000	571	3,017	3,398	388
350,000	611	3,231	3,639	409
400,000	649	3,429	3,861	427
450,000	684	3,613	4,069	444
500,000	716	3,786	4,264	460
600,000	777	4,106	4,624	489
700,000	832	4,397	4,951	515
800,000	883	4,666	5,254	538
900,000	930	4,916	5,537	560

Table 9-24. Functions of Loading Density

Loading Density w (lbs/ft^3)	Ground Shock f_g ($0.267\ w^{0.30}$)	Debris f_d ($0.600\ w^{0.18}$)
1.0	0.27	0.60
1.2	0.28	0.62
1.4	0.30	0.64
1.6	0.31	0.65
1.8	0.32	0.67
2.0	0.33	0.68
2.5	0.35	0.71
3.0	0.37	0.73
3.5	0.39	0.75
4.0	0.40	0.77
4.5	0.42	0.79
5.0	0.43	0.80
6.0	0.46	0.83
7.0	0.48	0.85
8.0	0.50	0.87
9.0	0.52	0.89
10.0	0.53	0.91
12.0	0.56	0.94
14.0	0.59	0.96
16.0	0.61	0.99
18.0	0.64	1.01
20.0	0.66	1.03
25.0	0.70	1.07
30.0	0.74	1.11
35.0	0.78	1.14
40.0	0.81	1.17
45.0	0.84	1.19
50.0	0.86	1.21
60.0	0.91	1.25
70.0	0.96	1.29
80.0	0.99	1.32
90.0	1.03	1.35
100.0	1.06	1.37

Table 9-25. Distances to Protect Against Hard Rock Debris.

Weight (lbs)	$C/W^{1/3}$ (ft/lb$^{1/3}$)							
	0.3	0.5	0.7	0.9	1.1	1.6	2.1	3
	D_{id}/f_d (ft)							
1000	163	180	200	205	195	145	92	62
1200	170	195	215	220	210	155	98	67
1400	185	210	230	235	225	165	105	72
1600	195	220	240	250	240	175	110	76
1800	205	230	250	260	250	180	115	79
2000	210	240	260	270	260	190	120	83
2500	230	260	290	300	290	210	135	91
3000	250	290	310	320	310	225	145	98
3500	270	300	330	340	330	240	155	105
4000	280	320	350	360	350	250	160	110
4500	300	340	370	380	360	260	170	115
5000	310	350	380	400	380	280	175	120
6000	330	380	410	430	410	300	190	130
7000	350	400	440	460	440	320	205	140
8000	370	430	470	480	460	330	215	145
9000	390	450	490	500	480	350	225	155
10000	410	470	520	520	500	370	235	160
12000	440	500	560	560	540	400	250	175
14000	470	540	580	600	580	420	270	185
16000	500	560	620	640	620	440	290	195
18000	520	600	640	680	640	470	300	205
20000	540	620	680	700	680	490	310	215
25000	600	680	740	760	740	540	340	235
30000	640	740	800	820	800	580	370	250
35000	680	780	860	880	840	620	390	270
40000	720	820	900	940	900	640	420	285
45000	760	860	940	980	940	680	440	295
50000	800	900	980	1000	980	700	460	310
60000	860	980	1050	1100	1050	760	490	335
70000	920	1050	1150	1150	1100	820	520	355
80000	960	1100	1200	1250	1100	860	560	375
90000	1000	1150	1250	1300	1250	900	580	395
100000	1050	1200	1300	1350	1300	940	600	410
120000	1150	1300	1400	1450	1400	1000	660	445
140000	1200	1400	1500	1550	1500	1100	700	475
160000	1300	1450	1600	1650	1600	1150	740	500
180000	1350	1550	1650	1750	1650	1200	780	525
200000	1400	1600	1750	1800	1750	1250	800	550
250000	1550	1750	1900	2000	1900	1350	880	600
300000	1650	1900	2050	2150	1500	1500	960	645
350000	1750	2000	2200	2250	2200	1600	1000	690
400000	1850	2100	2300	2400	2300	1650	1050	725
450000	1950	2200	2450	2500	2400	1750	1100	765
500000	2050	2300	2500	2600	2500	1800	1150	800
600000	2200	2500	2700	2800	2700	1950	1250	860
700000	2350	2700	2900	3000	2900	2100	1350	915
800000	2450	2800	3100	3200	3100	2200	1400	965
900000	2600	3000	3200	3300	3200	2300	1500	1015

Table 9-26. Distances to Protect Against Soft Rock Debris.

Weight (lbs)	$C/W^{1/3}$ ($ft/lb^{1/3}$)							
	0.2	0.6	0.75	0.9	1	1.5	1.75	2.5
	D_{id}/f_d (ft)							
1,000	165	200	207	198	184	91	62	30
1,200	177	216	223	213	199	98	67	32
1,400	189	230	238	227	212	105	72	34
1,600	200	243	251	240	224	110	76	36
1,800	210	255	264	252	235	116	79	38
2,000	219	266	275	263	245	121	83	40
2,500	240	292	302	288	268	133	91	43
3,000	258	314	325	311	289	143	98	47
3,500	275	335	346	331	308	152	104	50
4,000	291	354	366	350	326	161	110	53
4,500	305	371	384	367	342	169	116	55
5,000	319	388	401	383	357	176	121	58
6,000	343	418	432	413	384	190	130	62
7,000	366	445	460	440	409	202	139	66
8,000	386	470	486	464	433	214	147	70
9,000	405	493	510	487	454	224	154	74
10,000	423	515	532	509	474	234	161	77
12,000	456	555	574	548	511	252	173	83
14,000	486	591	611	584	544	269	184	88
16,000	513	624	645	617	575	284	195	93
18,000	539	655	677	648	603	298	204	98
20,000	562	684	707	676	630	311	213	102
25,000	616	750	775	741	690	341	234	112
30,000	664	808	835	798	744	367	252	120
35,000	707	861	890	851	792	391	268	128
40,000	747	909	940	898	837	413	283	136
45,000	784	954	986	943	878	434	297	142
50,000	819	996	1,030	985	917	453	311	148
60,000	882	1,074	1,110	1,061	988	488	335	160
70,000	940	1,144	1,182	1,130	1,053	520	357	170
80,000	993	1,208	1,249	1,194	1,112	549	377	180
90,000	1,042	1,268	1,311	1,253	1,167	576	395	189
100,000	1,088	1,324	1,368	1,308	1,218	602	413	197
120,000	1,172	1,426	1,475	1,410	1,313	648	445	213
140,000	1,249	1,520	1,571	1,502	1,399	691	474	226
160,000	1,319	1,605	1,659	1,586	1,477	730	500	239
180,000	1,384	1,684	1,741	1,665	1,550	766	525	251
200,000	1,445	1,759	1,818	1,738	1,619	800	548	262
250,000	1,584	1,927	1,992	1,905	1,774	876	601	287
300,000	1,707	2,077	2,147	2,052	1,911	944	648	310
350,000	1,818	2,212	2,287	2,186	2,036	1,006	690	330
400,000	1,921	2,337	2,416	2,309	2,151	1,062	729	348
450,000	2,016	2,453	2,535	2,424	2,257	1,115	765	366
500,000	2,105	2,561	2,647	2,531	2,357	1,164	798	382
600,000	2,268	2,760	2,853	2,727	2,540	1,254	860	411
700,000	2,416	2,940	3,039	2,905	2,705	1,336	917	438
800,000	2,552	3,105	3,210	3,068	2,858	1,412	968	463
900,000	2,678	3,259	3,369	3,220	2,999	1,481	1,016	486

Table 9-27. Values for Ratio, $D_{HYD}/V_E^{1/2.8}$

V_E (ft^3)	$D_{HYD}/V_E^{1/2.8}$ Effective Hydraulic Diameter, D_{HYD} (ft)					
	10	15	20	25	30	35
1,000	0.8483	1.2725	1.6967	2.1209	2.5450	2.9692
2,000	0.6623	0.9935	1.3246	1.6558	1.9869	2.3181
3,000	0.5730	0.8595	1.1460	1.4326	1.7191	2.0056
4,000	0.5171	0.7756	1.0341	1.2927	1.5512	1.8097
5,000	0.4775	0.7162	0.9549	1.1937	1.4324	1.6711
6,000	0.4474	0.6710	0.8947	1.1184	1.3421	1.5658
7,000	0.4234	0.6351	0.8468	1.0585	1.2702	1.4819
8,000	0.4037	0.6055	0.8074	1.0092	1.2110	1.4129
9,000	0.3871	0.5806	0.7741	0.9676	1.1612	1.3547
10,000	0.3728	0.5591	0.7455	0.9319	1.1183	1.3047
20,000	0.2910	0.4365	0.5820	0.7275	0.8731	1.0186
30,000	0.2518	0.3777	0.5036	0.6295	0.7554	0.8812
40,000	0.2272	0.3408	0.4544	0.5680	0.6816	0.7952
50,000	0.2098	0.3147	0.4196	0.5245	0.6294	0.7343
60,000	0.1966	0.2949	0.3931	0.4914	0.5897	0.6880
70,000	0.1860	0.2791	0.3721	0.4651	0.5581	0.6511
80,000	0.1774	0.2661	0.3548	0.4434	0.5321	0.6208
90,000	0.1701	0.2551	0.3401	0.4252	0.5102	0.5952
100,000	0.1638	0.2457	0.3276	0.4095	0.4914	0.5733
200,000	0.1279	0.1918	0.2557	0.3197	0.3836	0.4476
300,000	0.1106	0.1660	0.2213	0.2766	0.3319	0.3872
400,000	0.0998	0.1497	0.1997	0.2496	0.2995	0.3494
500,000	0.0922	0.1383	0.1844	0.2305	0.2766	0.3226
600,000	0.0864	0.1296	0.1727	0.2159	0.2591	0.3023
700,000	0.0817	0.1226	0.1635	0.2044	0.2452	0.2861
800,000	0.0779	0.1169	0.1559	0.1948	0.2338	0.2728
900,000	0.0747	0.1121	0.1495	0.1868	0.2242	0.2615
1,000,000	0.0720	0.1080	0.1439	0.1799	0.2159	0.2519
2,000,000	0.0562	0.0843	0.1124	0.1405	0.1686	0.1967
3,000,000	0.0486	0.0729	0.0972	0.1215	0.1458	0.1701
4,000,000	0.0439	0.0658	0.0877	0.1097	0.1316	0.1535
5,000,000	0.0405	0.0608	0.0810	0.1013	0.1215	0.1418

Table 9-28. Scaled IBD for Airblast without Mitigating Devices.[1,2,3]

NEW (lbs)	$r(\theta)/(D_{HYD}/V_E^{1/2.8})$ Horizontal Angle from Centerline Axis (Degrees)					
	0	30	60	90	120	180
1,000	1,545	1,290	895	621	452	273
2,000	1,979	1,653	1,146	795	579	349
3,000	2,287	1,910	1,325	919	669	404
4,000	2,535	2,117	1,468	1,019	741	448
5,000	2,745	2,292	1,590	1,103	803	485
7,000	3,096	2,585	1,793	1,244	905	547
10,000	3,516	2,936	2,037	1,413	1,028	621
20,000	4,504	3,761	2,609	1,810	1,317	795
30,000	5,206	4,347	3,015	2,092	1,522	919
40,000	5,769	4,818	3,341	2,319	1,687	1,019
50,000	6,247	5,217	3,619	2,511	1,827	1,103
70,000	7,045	5,883	4,081	2,831	2,060	1,244
100,000	8,002	6,683	4,635	3,216	2,340	1,413
200,000	11,977	10,002	6,937	4,813	3,502	2,115
250,000	13,633	11,384	7,896	5,479	3,987	2,407
500,000	17,462	14,582	10,114	7,018	5,106	3,083
700,000	19,691	16,444	11,406	7,914	5,759	3,477
1,000,000	22,367	18,678	12,955	8,989	6,541	3,949
2,000,000	28,649	23,925	16,594	11,514	8,378	5,059
3,000,000	33,113	27,652	19,180	13,308	9,684	5,847
5,000,000	39,740	33,187	23,018	15,972	11,622	7,017
7,000,000	44,815	37,424	25,957	18,011	13,106	7,913
10,000,000	50,903	42,509	29,484	20,458	14,886	8,988

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1 IBD for airblast without airblast mitigating devices:

$r(\theta)/(D_{HYD}/V_E^{1/1.4}) = 149.3 \bullet \{W^{0.5}/[p_{SO}(1+(\theta/56)^2)]\}^{1/1.4}$ (English Units)

where: $p_{SO} = 1.2$ psi — $W \leq 100{,}000$ lbs

$p_{SO} = 44.57 \bullet W^{-0.314}$ psi — $100{,}000 \leq W \leq 250{,}000$ lbs

$p_{SO} = 0.9$ psi — $W > 250{,}000$ lbs

2 Reduce IBD by 50% when portal barricade configured IAW COE Definitive Drawing 421-80-04 is used.

3 Reduce IBD as follows when a closure plug designed IAW COE Definitive Drawing 421-80-04 is used:

Reduction (%) = 0 % — $w \leq 0.0625$ lb/ft^3

Reduction (%) = 50 $\log_{10}(16.02 \bullet w)$ — $0.0625 < w \leq 0.625$ lb/ft^3

Reduction (%) = 50% — $w > 0.625$ lb/ft^3

H. Military working dog explosives search training

1. **General**. Realistic and effective training of military working dogs (MWD) involves simulated searches to detect explosives that have been hidden in various public places. These training operations typically include handling explosives, cutting or dividing explosive training aids, removing explosives from the shipping and storage containers, and repackaging explosives into other containers. For these reasons, training operations shall be conducted by qualified personnel only in facilities that meet the Q-D and other requirements of this Standard.

2. **Requirements**. The following safety precautions are required for MWD training exercises.

a. Store explosives in facilities that meet Q-D and other requirements of this Standard.

b. Persons not essential to dog training must not be exposed to an accidental explosion during a training exercise. Evacuate nonessential personnel $D = 40\ W^{1/3}$ from the training site, if more than 15 total pounds of explosives are being used for the exercise. For 15 total pounds of explosives or less, the distance shall be a minimum of 100 feet.

c. Minimize the number of samples and the quantity of explosives for each sample. The cognizant DoD Component shall determine the total quantity of explosives permitted during an exercise considering:

(1) The value and importance of the exposed facilities;

(2) The exercise operating conditions; and,

(3) The availability of evacuation space for nonessential personnel.

d. Deploy samples a sufficient distance apart to prevent an explosion from propagating from one sample to another.

e. Do not use blasting caps, squibs, explosive detonators, or any initiating explosive for training.

f. Do not place explosives near any heat or spark producing items such as bare electrical wiring, radiators, electric heaters, heating vents, or any other source of potential initiation.

g. Do not place explosives in metal containers or other confinements that would act as a source of fragments in the event of an accidental explosion.

CHAPTER 10

THEATER OF OPERATIONS QUANTITY-DISTANCE

A. General

Provisions of this Chapter apply only to essential DoD ammunition and explosives activities outside the United States, its territories, and its possessions when full compliance with other Chapters of this Standard is not possible, but the activities are permitted by host nation laws and/or Status of Forces Agreements. Use of this Chapter shall be authorized specifically by the responsible major commander.

B. Basic load ammunition holding areas (BLAHA)

1. General. To fulfill their missions, certain units must keep their basic load ammunition in readiness within the boundaries of their barracks or in the immediate vicinity thereof, in armored vehicles, trucks, trailers, structures, or on pads. This involves acceptance of risks to unit personnel, facilities, and equipment that are greater than permitted by other Chapters of this Standard. Minimum fragment distance requirements of subsection E.2., Chapter 2, apply for exposures involving nonmilitary personnel, family housing, health and morale facilities.

2. **Mixing of basic load ammunition**. Storage compatibility requirements (Chapter 3) do not apply to BLAHA facilities.

3. **Net explosive quantity (NEQ).**[1] For Q-D computations, the following explosives will be excluded in determining the NEQ in a BLAHA:

a. Propelling charges in Hazard Division 1.2 fixed, semifixed, mortar, and rocket ammunition.

b. The quantity of explosives in Hazard Division 1.3 items, unless the site contains only Hazard Division 1.3, in which case Hazard Division 1.3 Q-D in Chapter 9 apply. In the application of this paragraph to separate loading ammunition, an equal number of propelling charges may be stored with the separate loading projectiles.

4. **Explosives limits**. The maximum NEQ at any site in a BLAHA storing mixed compatibility basic load ammunition must not exceed 4000 kg.

5. **Quantity distance computations**

a. The total NEQ of ammunition in each single armored vehicle (light or heavy) shall be used for computation of Q-D.

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[1] For Chapter 10 only, the amount of explosives material and the distance between a PES and ES are measured in kilograms (kg) and meters (m), respectively. The term NEQ is used to make the distinction.

b. The total NEQ of ammunition in each truck or trailer shall be used for the computation of Q-D provided the trucks and trailers are separated from each other by at least the D1 distances in Table 10-1 if barricaded, or D3 distances if unbarricaded.

c. The total NEQ of ammunition in all trucks or trailers within a truck or trailer park shall be used for Q-D computations if the trucks or trailers within a park are not separated from each other by quantity-distances specified in paragraph B.5.b., above.

d. Intermagazine separation requirements of Chapter 9 apply when basic load ammunition is stored in standard magazines. When earth-covered shelters of light construction are used, the D1 distances in Table 10-1 apply to side-to-side configurations provided the earth-cover complies with subsection C.4., Chapter 5, and the explosives are stored at least 1 meter from the end of the shelter. If end-to-end exposures are involved, the D2 distances in Table 10-1 apply provided there is a barricade.

e. The D6 distances of Table 10-1 are used both as public traffic route distances and inhabited building distances from vehicles with heavy armor, since the heavy armor is expected to contain fragments. The D6 distances are based on blast impulse only.

f. The D4 and D5 distances in Table 10-1 shall be used as public traffic route distances and inhabited building distances, respectively, from vehicles with light armor, since light armor is not expected to contain fragments.

g. Barracks, headquarters, and maintenance facilities within a military installation shall be separated from trucks and trailers of basic load ammunition by the D5 distances in Table 10-1.

h. D4 distances in Table 10-1 shall be used as public traffic route distances from trucks and trailers of basic load ammunition.

i. Chapters 2 and 9 Q-D criteria may be used provided proper storage compatibility (see Chapter 3) is observed, and if the propellant and other Hazard Division 1.3 items are included in the determination of the NEW instead of NEQ limitations addressed in subsection B.3., above.

C. Airfields used only by military aircraft

1. General

a. Air forces operate in war from the same locations that they occupy in peacetime. Consequently, it may be necessary to store or hold weapons and ammunition as close to the aircraft as possible without exposing personnel or facilities to unacceptable risk from an accidental explosion or the detonation of weapons or ammunition as a result of enemy actions in war. The following standards in this section provide the minimum levels of protection deemed necessary.

Table 10-1. Quantity-Distances for Basic Load Ammunition Holding Areas.

Net Explosive Quantity Q (kg)	Quantity-Distances (meters)					
	D1	D2	D3	D4	D5	D6
50	3	7	18	180	270	20
75	3.5	8	21	180	270	26
100	4	9	23	180	270	32
125	4	9	24	180	270	38
150	4.5	26	26	180	270	42
175	4.5	11	27	180	270	
200	5	11	28	180	270	
250	6	12	31	180	270	
300	6	13	33	180	270	
350	6	13	34	180	270	
400	6	14	36	180	270	
450	7	14	37	180	270	
500	7	15	39	180	270	
600	7	16	41	180	270	
700	8	16	43	180	270	
800	8	17	45	180	270	
900	8	18	47	180	270	
1000	8	18	48	180	270	
1200	9	20	52	180	270	
1400	9	21	54	180	270	
1600	10	22	57	180	270	
1800	10	22	59	180	270	
2000	11	23	61	180	270	
2500	11	25	66	185	275	
3000	12	26	70	205	305	
3500	13	28	73	220	330	
4000	13	29	77	235	350	
Distance Functions	$D1 = 0.8Q^{1/3}$	$D2 = 1.8Q^{1/3}$	$D3 = 4.8Q^{1/3}$	$D4 = 3.6Q^{1/2}$	$D5 = 5.5Q^{1/2}$	

b. The Q-Ds specified herein apply essentially to PESs that exist in peacetime. Commanders shall decide the Q-Ds to be applied to sites that only become PESs in emergencies or wartime and such distances shall be accounted for in the airfields' peacetime layout. In reaching his decision, the Commander shall consider that, in the event of an explosion at the PES, a reduction in specified distances to nonoperationally essential facilities may result in increased damage and casualties, while a similar reduction for operationally essential facilities may result in the facility ceasing to function and the prejudicing of operational plans.

c. The more essential military resources may require additional protection.

d. Aircraft that contain only installed explosives and safety devices such as authorized signals in survival kits, egress systems components, engine-starter cartridges, fire extinguisher cartridges and other such items (see paragraph D.1.a., Chapter 9) necessary to flight operations are not regarded as PESs under the provisions of this Chapter.

2. **Q-Ds**. The following Q-Ds which assume Hazard Division 1.1 loads may be used for all hazard divisions. When other Chapters permit, lesser distances may be used for hazard divisions other than 1.1.

a. **Q-Ds between aircraft loaded with explosives** (Table 10-2)

(1) Unbarricaded individual aircraft or groups of aircraft loaded with explosives must be separated one from another by $12Q^{1/3}$ distance unless space limitations or operational considerations dictate otherwise. At these distances, adjacent individual aircraft or groups of aircraft may sustain damage due to fragments but should, in most cases, remain operable. When complete protection against fragments is deemed necessary, a separation distance of 270 m shall be provided. Individual or groups of aircraft shall be separated by $7.2Q^{1/3}$ distances to protect against propagation of detonation. If the aircraft carry ammunition of comparable resistance to propagation as robust shells, $4.4Q^{1/3}$ distances may be used to protect against simultaneous detonation.

(2) Barricades between adjacent aircraft will prevent simultaneous propagation due to high velocity-low angle fragments. It should be noted, however, that a barricade does not necessarily prevent subsequent propagation or damage caused by blast, lobbed items, debris, or secondary fires.

b. **Q-Ds to runways, taxiways and combat and cargo aircraft**. When real estate constraints and operational necessity dictate and the transient risk to military aircraft movement is accepted, PESs (not including combat and cargo aircraft) may be separated from runways and taxiways by not less than $1.8Q^{1/3}$ distances, Table 10-2. If the transient risk is not accepted, $12Q^{1/3}$ distances shall be used to provide protection to the aircraft on these runways and taxiways. There are no separation distances required from combat and cargo aircraft to military runways and taxiways. However, for joint use (military and commercial) runway and taxiways the following separation distance from PES (including combat and cargo aircraft) apply: $22.2Q^{1/3}$ to joint use runways and $3.6Q^{1/2}$ ($Q<4{,}500$ kg) or $14.8Q^{1/3}$ ($Q \geq 4{,}500$ kg) to joint use taxiways. Runways and taxiways are not considered to be a PES.

c. **Q-Ds between hardened aircraft shelters (HASs) and associated storage facilities**

(1) As a minimum, HASs and associated storage facilities shall be separated one from another according to Table 10-3. At these distances there will be a high degree of protection against propagation of explosion, however, the exposed shelter may be damaged heavily and aircraft and ammunition therein may be rendered unserviceable.

(2) HASs and associated storage facilities spaced according to Table 10-4 will prevent propagation between such facilities. An explosion in one shelter or ready storage facility may destroy it and its contents, but aircraft within adjacent shelters will be undamaged provided the doors are closed. These aircraft may not be immediately removable due to debris.

(3) Areas of hazard to front, side, or rear of HASs or igloos as PESs or ESs lie in the arcs shown in Figure 10-1. A particular face of an ES is deemed to be threatened by a PES face when both these faces lie within the arc of threat or hazard of the other.

d. **Q-Ds to facilities and activities in direct support of flightline and aircraft servicing**. When explosives are present on a long term basis, the PES shall be separated from the

squadron operations buildings, flightline maintenance functions, flightline fire and rescue stations, and other activities in direct support of flightline and aircraft servicing (such as alert crew, POL, and LOX facilities) by $7.2Q^{1/3}$ distances, Table 10-2, unless the facilities are hardened to provide comparable protection at lesser distances.

e. **Q-Ds to military aircraft not loaded with explosives**. Military aircraft not loaded with explosives (such as, tankers and transports) shall be separated from PESs by at least $12Q^{1/3}$ distances, Table 10-2. At these distances, the aircraft may be damaged by fragments but should remain operable.

f. **Q-Ds to open stacks of ammunition**. Barricaded open storage of ammunition is permitted at not less than $12Q^{1/3}$ distances, Table 10-2, from unsheltered parked aircraft.

g. **Q-Ds to general public and central airfield support facilities** (Table 10-2).

(1) Use $14Q^{1/3}$ distances from the rear and $18Q^{1/3}$ distances from the sides and front of ready service igloos containing up to 10,000 Kg NEQ at loading densities of up to 20 Kg/m^3. Apply minimum fragment distances of 270 m to central airfield support facilities and public traffic routes having traffic densities not exceeding 60 vehicles per hour, and 400 m to general public facilities and public traffic routes having traffic densities exceeding 60 vehicles per hour.

(2) When the PES is a third-generation HAS containing up to 5,000 Kg NEQ, minimum distances from the front, sides, and rear given in Table 10-5 shall be used to protect an unhardened exposed site against debris and blast. The quantity-distance criteria given in Table 10-5 apply to all Hazard Division 1.1 ammunition and explosives regardless of any minimum fragment distance denoted by (xx) 1.1.

(3) Use $22.2Q^{1/3}$ distances for other PES when explosives are present on a long term basis, and apply minimum fragment and debris distances of 270 m or 400 m depending on the nature of the PES (open-stack or lightweight structure versus igloo or heavy-walled structure) and the population density at the ES (25 or less persons versus more than 25 persons).

(4) Where the ES have been hardened, lesser distances may be used, depending on the degree of hardening provided.

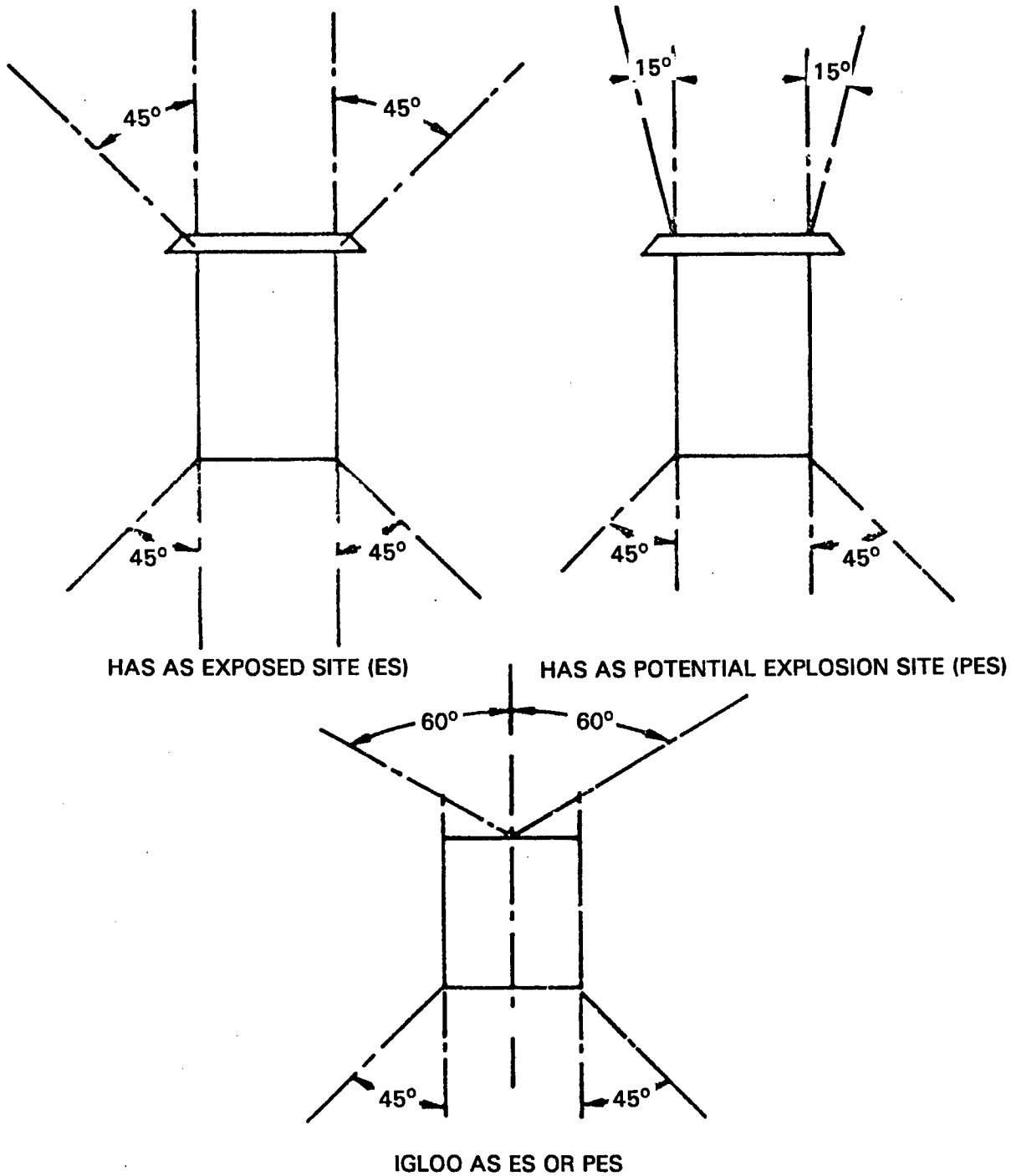

Figure 10-1. Areas of Hazard

Table 10-2. Hazard Division 1.1 Quantity-Distance for Airfields Used Only by Military Aircraft in Theaters of Operation.

Net Explosive Quantity Q (kg)	Distance (meters)								
	$0.5Q^{1/3}$	$0.8Q^{1/3}$	$1.1Q^{1/3}$	$1.8Q^{1/3}$	$2.0Q^{1/3}$	$2.4Q^{1/3}$	$3.2Q^{1/3}$	$3.6Q^{1/3}$	$4.4Q^{1/3}$
500	4	6	9	15	16	20	25	29	35
600	5	7	10	16	17	21	27	31	38
700	5	7	10	16	18	22	28	32	40
800	5	7	11	17	19	23	30	34	41
900	5	8	11	18	19	24	31	35	43
1000	5	8	11	18	20	24	32	36	44
1200	6	9	12	20	21	26	34	39	47
1400	6	9	13	21	22	27	36	41	50
1600	6	9	13	22	23	29	37	43	52
1800	7	10	14	22	24	30	39	44	54
2000	7	10	14	23	25	31	40	46	56
2200	7	10	14	24	26	31	42	47	57
2500	7	11	15	25	27	33	43	49	60
3000	8	12	16	26	29	35	46	52	64
3500	8	12	17	28	30	37	49	55	67
4000	8	13	18	29	32	39	51	58	70
4400	8	13	18	30	33	39	52	59	72
5000	9	14	19	31	34	42	55	62	76
6000	10	15	20	33	36	44	58	66	80
7000	10	15	22	35	38	46	61	69	85
8000	10	16	22	36	40	48	64	72	88
9000	11	17	23	38	42	50	67	75	92
10000	11	17	24	39	43	52	69	78	95

Table 10-2. Hazard Division 1.1 Quantity-Distances for Airfields Used Only by Military Aircraft in Theaters of Operation. (Continued)

Net Explosive Quantity Q (kg)	Distance (meters)							
	$7.2Q^{1/3}$	$12Q^{1/3}$	$14Q^{1/3}$	$16Q^{1/3}$	$18Q^{1/3}$	$20Q^{1/3}$	$22.2Q^{1/3}$	$25Q^{1/3}$
500	58	95	111	130	145	160	180	200
600	61	100	118	135	155	170	190	215
700	64	105	124	145	160	180	200	225
800	67	110	130	150	170	190	210	235
900	70	115	135	155	175	195	215	245
1000	72	120	140	160	180	200	225	250
1200	77	130	148	175	195	215	240	270
1400	81	135	157	180	205	225	250	280
1600	85	140	164	190	215	235	260	295
1800	88	145	171	195	220	245	275	305
2000	91	150	176	205	230	255	280	315
2200	94	155	185	210	235	265	290	330
2500	98	165	190	220	245	275	305	340
3000	105	175	202	235	260	290	325	365
3500	110	180	213	245	275	305	340	380
4000	115	190	223	255	290	320	355	400
4400	120	200	230	260	295	330	365	410
5000	125	205	239	275	310	345	380	430
6000	135	220	255	295	330	365	405	455
7000	140	230	267	310	345	385	425	480
8000	145	240	280	320	360	400	445	500
9000	150	250	291	335	375	420	465	525
10000	160	260	301	345	390	435	480	540

Table 10-3. Quantity-Distances for Propagation Prevention.

To ES		1st Gen. Hardened Aircraft Shelters			2nd & 3rd Gen. Hardened Aircraft Shelters			Ready Service Igloo				Ready Service Above Ground Magazine	
From PES		S	R	F	S	R	F	S	R	FB	FU	B	U
1st Generation Hardened Aircraft Shelter	S	0.8	0.8	2.4	0.8	0.8	1.8	0.8	0.8	1.1	2.4	1.1	4.4
	R	0.8	0.8	1.8	0.8	0.8	1.1	0.8	0.8	1.1	1.8	1.1	4.4
	F	1.1	1.1	3.2	1.1	1.1	2.0	1.1	1.1	2.0	3.2	2.4	4.4
2nd & 3rd Generation Hardened Aircraft Shelters[1]	S	0.8	0.8	2.4	0.8	0.8	1.8	0.8	0.8	1.1	2.4	1.1	4.4
	R	0.8	0.8	1.8	0.8	0.8	1.1	0.8	0.8	1.1	1.8	1.1	4.4
	F	1.1	1.1	3.6	1.1	1.1	2.4	1.1	1.1	2.4	3.6	2.4	4.4
Ready Service Igloo[2]	S	0.5[3]	0.5[3]	0.5[4]	0.5[3]	0.5[3]	0.5[3]	Use distances from Chapter 9[5]					
	R	0.5[3]	0.5[3]	1.1[4]	0.5[3]	0.5[3]	0.5[3]						
	FB	1.1[4]	1.1	2.4	1.1	1.1	1.1						
	FU	1.1[4]	1.1	3.6	1.1	1.1	1.1						
Above-Ground Magazines[6]	B	1.1	1.1	2.4	1.1	1.1	1.1						
	U	1.1	1.1	3.6	1.1	1.1	1.1						
Storage Area Igloo	S	See Table 10-4.											
	R												
	FB												
	FU												
Storage Area Above Ground Magazine	B												
	U												

Legend: S - side; R - rear; F - front; B - barricaded; U - unbarricaded.
Multiply units shown in table by $Q^{1/3}$.
Notes:

1 Limited to a maximum of 5,000 kg per shelter.
2 Ready service igloo storage is limited to 10,000 kg per magazine and loading density not more than 20 kg per cubic meter.
3 Use $0.8Q^{1/3}$ distance where the loading density exceeds 20 kg per cubic meter.
4 The loading density limitation of 20 kg per cubic meter not to be applied.
5 Units of measure in Chapter 9 are in ft and lbs. Conversion factors between kg and lbs, as well as between m and ft will be necessary.
6 Ready service above ground magazine storage is limited to 10,000 kg per magazine.

Table 10-4. Quantity-Distances for Assets Preservation.

To ES		1st Gen. Hardened Aircraft Shelters			2nd & 3rd Gen. Hardened Aircraft Shelters		
From PES		S	R	F	S	R	F
1st Generation Hardened Aircraft Shelter	S	3.6	3.2	7.2	3.6	3.2	4.4
	R	2.4	2.0	7.2	2.4	2.0	3.6
	F	3.6	3.2	7.2	3.6	3.2	7.2
2nd & 3rd Generation Hardened Aircraft Shelters[1]	S	3.6	3.2	7.2	3.6	3.2	4.4
	R	2.4	2.0	7.2	2.4	2.0	3.6
	F	3.6	3.2	7.2	3.6	3.2	7.2
Ready Service Igloo[2]	S	1.1	1.1	4.4	1.1	1.1	1.1
	R	1.1	1.1	3.6	1.1	1.1	1.1
	FB	3.2	3.2	7.2	3.2	3.2	3.2
	FU	3.2	3.2	7.2	3.2	3.2	3.2
Above-Ground Magazine[3]	B	3.2	3.2	7.2	3.2	3.2	3.2
	U	3.2	3.2	7.2	3.2	3.2	3.2
Storage Area Igloo	S	2.0	2.0	7.2	2.0	2.0	2.0
	R	2.0	2.0	7.2	2.0	2.0	2.0
	FB	3.2	3.2	7.2	3.2	3.2	3.2
	FU	3.2	3.2	7.2	3.2	3.2	3.2
Storage Area Above Ground Magazine	B	3.2	3.2	7.2	3.2	3.2	3.2
	U	3.2	3.2	7.2	3.2	3.2	3.2

Legend: S - side; R - rear; F - front; B - barricaded; U - unbarricaded.
Multiply units shown in table by $Q^{1/3}$.

Notes:
1 Limited to a maximum of 5,000 kg per shelter.
2 Ready service igloo storage is limited to 10,000 kg per magazine and loading density not more than 20 kg per cubic meter.
3 Ready service above ground magazine storage is limited to 10,000 kg per magazine.

Table 10-5. Quantity-Distances from a U.S. Third-generation Hardened Aircraft Shelter PES to an Unhardened Exposed Site.[1,2]

NEQ (kg)		Note	Front (meters)	Sides (meters)	Rear (meters)
from (>)	to				
0	2	[3]	15	15	15
2	50	[3]	70	15	15
50	225	[3]	70	15	15
225	500	[3]	70	120	50
500	5,000	[4]	$20Q^{1/3}$	$25Q^{1/3}$	$16Q^{1/3}$

Notes:

1. Separations are based on shelter doors remaining closed, except for aircraft towing, fueling, servicing, runup, or taxi and during integrated combat turnarounds or short periods when maintenance equipment or munitions are being moved into or out of the shelter. Where doors are left open for extended periods, normal combat aircraft parking area criteria apply.
2. Munitions should be separated from the hardened aircraft shelter walls at a distance sufficient to eliminate local breaching. For less than 500 kg, a one meter separation from the wall is sufficient.
3. The quantity-distance criteria in the table apply to inhabited building distance, public traffic route, and intraline exposures for quantities less than or equal to 500 kg.
4. For quantities greater than 500 to 5,000 kg, the quantity-distance criteria in the table only apply to inhabited building distance exposures. Use 50% of the inhabited building distance criteria for public traffic route exposures with a 91 meter minimum distance (out the front or rear) or a 120 meter minimum distance (off the sides). Use 35% of the inhabited building distance criteria for intraline exposures with a 91 meter minimum distance (out the front and rear) or a 120 meter minimum distance (off the sides).

CHAPTER 11

CHEMICAL AGENT STANDARDS

A. Scope and applicability

1. This Chapter sets forth standards for protecting workers and the general public from the harmful effects of chemical agents associated with research, testing, training, preservation and maintenance operations, storage, and demilitarization at laboratories, manufacturing plants and depots as well as other DOD Component agent operations, exclusive of combat training and operations. They apply to mustards: H/HD - 2,2' dichlorodiethyl sulfide, H/HT - 60% HD and 40% 2,2' dichloroethylthiodiethyl ether, L - dichloro (2-chlorovinyl) arsine; and to nerve agents: GB - isopropyl methylphosphonofluoridate, GA -dimethylaminoethoxy-cyanophosphine oxide, VX - 0-ethyl S-[2-(diisopropylamino) ethyl] methylphosphonothioate, and GD-pinacolyl methylphosphonofluoridate, as well as mixtures of these agents.

2. Ammunition containing chemical agents may present additional hazards of blast, fragments, and thermal effects. Standards relating to explosives hazards are addressed in other Chapters and are applicable herein.

3. Airborne Exposure Limits (AELs) established by The Army Surgeon General are maximum permissible concentrations.

4. This Standard does not apply when the immediate disposal of chemical ammunition or decontamination of chemical agents is necessitated by an emergency and when delay clearly will cause a greater danger to human life or health.

5. DoD Components are responsible for developing implementing instructions and safety procdures for logistical movements, training, and field operations.

6. The requirements of DoD 5000.2-R (reference (q)) and MIL-STD-882B (reference (r)) shall be followed.

B. Airborne exposure limits

1. Defense installations siting criteria

a. **Hazard zone calculations.** Hazard zone calculations will conform with DDESB Technical Paper No. 10 (reference (o)). For accident/incident control, downwind hazard models (consistent with Tech Paper 10) that account for terrain effects and changing meteorological conditions may be used. For agent-filled ammunition without explosives, the maximum credible event (MCE) factors shall include the number of items likely to be involved, the quantity of agent released, and the percentage of that quantity that will be disseminated. For ammunition with explosives components, the MCE shall be based on a detonation of the explosive components that will produce the worst results regarding release of agent. The propagation characteristics of the ammunition shall be considered in developing the overall MCE. The amount of agent released and the nature of release (evaporation or aerosolization) as a result of the MCE shall then be used to make the hazard-zone calculations for each agent as required by this Standard.

b. **Installation siting criteria**. The hazard zone (one percent lethality distance) calculated from the MCE shall represent that arc from the agent source containing a dose of more than 10.0, 4.3, and 150.0 mg-min/m^3 of GB, VX, or mustards, respectively and 0.1 mg for inhalation-deposition of VX. Positive means shall be taken to ensure that unprotected personnel do not enter such areas as defined. Positive means shall include written procedures that must be reviewed and updated, as necessary. Positive control of an area, which can ensure that personnel can evacuate or be protected before exposure in the case of an MCE, may be developed instead of absolute exclusion. Details of such control procedures shall be included in the site and general construction plans review.

c. **Controlled agent releases**. When by the nature of the operations a release of agent is expected (such as in the case of emergency destruction, training, or certain preventive maintenance operations), calculations shall ensure that personnel are protected within the limits established in Table 11-1.

Table 11-1. Airborne Exposure Limits.

	Chemical Agents (mg/m^3)				
	GD	GA/GB	VX	H,HD,HT	L (Note 1)
Unmasked Agent Worker					
8-hour TWA in any work shift	3×10^{-5}	1×10^{-4}	1×10^{-5}	3×10^{-3} (Note 2)	3×10^{-3} (Note 2)
Non-agent Worker and General Population					
72-hour TWA	3×10^{-6}	3×10^{-6}	3×10^{-6}	1×10^{-4} (Note 3)	3×10^{-3} (Note 2)
Ceiling Value (maximum for time period)	3×10^{-5}	1×10^{-4}	1×10^{-5}	3×10^{-3} (Note 2)	3×10^{-3} (Note 2)
Source Emission Limit					
1-hour TWA	1×10^{-4}	3×10^{-4}	3×10^{-4}	3×10^{-2}	3×10^{-2}

Ceiling value normally refers to the maximum at any time, for any duration. Practically, it may be an average value over the minimum time to detect the specified concentration.

Notes:
1 All concentrations measured as lewisite.
2 This value also represents the technologically feasible real time detection limit. HT is measured as HD.
3 It is recommended that this level of detection (using a 12-hour sampling time) be demonstrated and used at all sites where mustard shall be transported and destroyed.

2. Workplace AELs

AELs are listed in Table 11-1. AELs are time weighted average (TWAs) or ceiling values which define the permissible limits of exposure for unprotected personnel. Unmasked personnel may not be even briefly exposed to concentrations of chemicals greater than three times the 8-hour TWA concentrations.

C. Agent exposure control and measurement

1. Initial hazard analysis and exposure measurement

a. A hazard analysis shall be conducted for all new operations involving chemical agents or whenever there is a change in production, process, or control measures that may result in an increase in airborne or contact concentrations of chemical agents. If the hazard analysis indicates that any operation may expose personnel to chemical agents above the AEL, control measures shall be instituted and procedures shall be established so that the actual exposure will be measured. The written record of the initial hazard analysis shall be retained as a 40-year record.

b. The operation will be conducted in a manner that minimizes the public risk.

2. Methods of measurement

a. Devices for sampling and analyzing workplace air shall measure and alarm within 10 minutes when chemical agents are present in excess of the 8-hour TWA concentrations.

b. When the interior of reservoirs, pipes and such systems are sampled, the volume of the area being sampled as well as the volume of the sample must be recorded and associated with the results.

c. Decontaminating solutions will not be analyzed for residual agent for the purpose of certifying a level of decontamination. Suspected agents will be extracted from samples with suitable solvents where analyses are required. Air may be an appropriate solvent for volatile agents.

3. Exposure control

a. When exhaust systems are used to control exposure, measurements of system effectiveness such as static pressure shall be made at the start of each operation and at least every 3 months.

b. Before beginning chemical operations, a determination shall be made that the hazard zone associated with those operations is under positive control in accordance with subsection B.1., above.

c. If personnel exposures will equal or exceed the applicable AEL, personnel shall be protected by the use of personnel protective equipment (PPE) specifically approved by the DoD Component medical authority concerned or as indicated in Table 11-2.

d. Procedures will be developed to address hazards involved in maintenance and repair operations.

Table 11-2. Protective Equipment for Regulated Areas (Note 1) Employee Exposure Potential. (Note 2)

Occupational Scenario	Chemical Agents (mg/M^3)				
	GD	GA/GB	VX	H,HD, & HT	L
1. Unmasked Agent Worker					
A full facepiece, chemical canister, air purifying protective mask shall be on hand for escape. (The M9, M17 or M40 series masks are acceptable for that purpose. Other masks certified as equivalent may be used.) (Note 5)	$\leq 3 \times 10^{-5}$ (Note 3)	$\leq 1 \times 10^{-4}$ (Note 3)	$\leq 1 \times 10^{-5}$ (Note 3)	3×10^{-3} (Note 4)	3×10^{-3} (Note 4)
2. Masked Personnel in Routine Operations					
a. A NIOSH and/or MSHA approved pressure demand full facepiece SCBA or supplied air respirator with escape air cylinder may be used. b. Alternatively, a full facepiece, chemical canister air purifying protective mask is acceptable for that purpose (i.e., M9, M17, or M40 series or other certified equavalent.) (Note 5)	$>3 \times 10^{-5}$ to 6×10^{-2}	$>1 \times 10^{-4}$ to 2×10^{-1}	$>1 \times 10^{-5}$ to 2×10^{-2}	$\leq 3 \times 10^{-3}$	$\leq 3 \times 10^{-3}$
3. Operations Personnel Conducting Emergency Operations or Operations in Unknown but Potentially High Agent Concentrations					
a. NIOSH and/or MSHA approved pressure demand full facepiece SCBA suitable for use in high concentrations agent with protective ensemble. (Notes 7 & 8) b. During emergencies, the best available respiratory protection and personnel ensemble must be used. If protection in 3a above is not available, use of a full facepiece, chemical canister, air purifying protective mask with hood is acceptable. Only the M9 series mask with Mil canister is acceptable. (Notes 7 & 8)	$>6 \times 10^{-2}$	$>2 \times 10^{-1}$	$>2 \times 10^{-2}$	$>3 \times 10^{-3}$ (Note 6)	$>3 \times 10^{-3}$ (Note 6)

Notes for Table 11-2:

1 Qualitatively fit all workers required to use respiratory protective devices. Quantitative fit testing may be performed using surrogate masks.

2 Based on an 8-hour TWA measurement. All values on this table are 8 hour TWA unless otherwise noted. The TWA is the concentration to which nearly all workers may be repeatedly exposed, for a normal 8-hour workday and 40-hour workweek, day after day, without adverse effects. TWAs permit excursions above the limit provided they are compensated by equivalent excursions below the limit during the workday. Excursions above the TWA should be controlled even where the 8-hour TWA is within recommended limits.

3 Determined by required continuous air monitoring.

Notes for Table 11-2 (continued):

4 This represents ceiling value determined by continuous real time monitoring (with alarm) at the 0.003 mg/m^3 level of detection; immediate respiratory protection available in case concentration rises above 0.003 mg/m^3; potential exposure by any route limited by engineering and work practice controls to the extent practicable.

5 Air-purifying masks may NOT be used in oxygen deficient atmospheres.

6 Due to the potential carcinogenicity of agents H and L, the highest level of respiratory and dermal protection should be provided to all workers exposed; i.e., a NIOSH and/or MSHA approved, pressure demand, full facepiece SCBA or supplied air respirator suitable for use in high concentration atmospheres. An air-purifying protective mask is not suitable for this purpose.

7 Examples of such protective ensembles include toxicologic agent protective ensemble, self-contained (TAPES) and the demilitarization protective ensemble (DPE).

8 For emergency masked escape, a full facepiece, chemical canister, air-purifying protective mask (M9, M17, or other certified equivalent) is acceptable.

D. Medical surveillance

Preassignment and annual health assessments shall be provided for each employee to establish a baseline health record and to provide counseling on health matters as related to the chemical agent operations. Annual assessments will be used to determine deviations from the baseline.

E. Worker protective clothing and equipment

1. Positive engineering and administrative controls shall be incorporated in all operations involving chemical agents to preclude or minimize the need for personal protective equipment.

2. A respiratory protection program shall be established in conformance with DoD Instruction 6055.1 (reference (s)) for approved respiratory requirements. The wearer's face shall be clean-shaven to the extent that there is no interference of any facial hair growth with the sealing surfaces of the protective mask. Personnel with beards shall be denied access to agent storage and operating areas, unless suitable emergency egress respirator(s) can be provided.

3. Personnel shall use approved protective clothing as determined by the hazard analysis.

F. Administrative and work practice controls

1. Containment

a. Containment is the principal control measure for prevention of exposure of personnel to agents from inherently hazardous operations.

(1) Total containment requires the equipment or facility to be of a tested design capable of containing all the reaction gases, detectable agent, and fragments from the largest explosion or detonation that could occur without causing equipment or facility rupture or leakage. Total containment is required for those operations involving ammunition that contain explosive components as well as agents, whenever the operation may subject the explosive components to a potential initiating stimulus. Operations requiring total containment include:

(a) Chemical ammunition cutting, sawing, milling, drilling, punching, or shearing operations that require the machine tool to remove or displace metal before or after contact with the explosives.

(b) Operations in which the ammunition arming and functioning environments can be duplicated by the equipment or process.

(c) Disassembly of armed or possibly-armed ammunition.

(d) Disassembly of explosive components from ammunition that requires application of significantly greater leverage or torque than that required for assembly.

(2) Vapor containment requires the equipment or facility to be of a tested design capable of containing nonexplosion releases of agent. Vapor containment is required for those operations involving agents without explosives components and for those operations involving ammunition containing both agent and explosive components that do not subject the explosive components to a potential initiating stimulus. Operations requiring vapor containment include:

(a) Chemical ammunition punching, drilling, or sawing operations for removal of agents.

(b) Burster-well removal.

(c) Transfer of agent from bulk storage tanks, containers, or ammunition into holding tanks, chemical detoxification reactors, incinerators, or similar processing equipment, such as may be found in a production, demilitarization, or disposal line. This is not to be construed as requiring vapor containment for agent transfer during field operations involving leaker repair activities.

(d) RDT&E Test Chamber operations.

b. Containment is not required for operations associated with field storage and maintenance activities (such as shipping, storage, receiving, rewarehousing, minor maintenance, surveillance inspection, repair, encapsulation and emergency agent transfer in the event of leakage).

2. **Training and information**. All who work directly with chemical agents and ammunition (agent workers, firefighters, medical, and security personnel) shall receive enough training to enable them to work safely and to understand the relative significance of agent exposures. This training shall include information on sources of exposure, possible adverse health effects, practices and controls being used to limit exposures, environmental issues, medical monitoring procedures in use and their purposes, and employee responsibilities in health protection programs. In addition

to this training, fire protection workers shall be familiar with the contents of the following references:

a. Chemical Agent Data Sheets (reference (t)).

b. Joint Chemical Biological (CB) Technical Data Source Book (reference (u)).

c. Special Occupational Safety and Health Standard for the Evaluation and Control of Occupational Exposure to Agent GB (reference (v)).

3. **Recordkeeping**. Recordkeeping pertaining to exposure determination and measurement, mechanical ventilation, employee training, medical surveillance, and access to records shall be consistent with DoD Instruction 6055.5 (reference (w)).

4. **Labeling and posting of hazards**

a. Signs and labels to warn personnel of hazards of chemical agents are required for work areas, for containers of chemical agents, for contaminated clothing and equipment, and for identification of restricted-use areas.

b. When opportunity for agent contamination exists, equipment, tools, or other items shall be marked, tagged or segregated to indicate degree of decontamination undergone or that the facility or item never has been exposed to chemical agents, whichever is appropriate.

(1) An agent symbol with a single "X" indicates the item has been partially decontaminated of the indicated agent. Further decontamination processes are required before the item is moved or any maintenance or repair is performed without the use of chemical protective clothing and equipment. This degree generally shall be applied to the item as it stands in place after being used and subjected only to routine cleaning after use.

(2) An agent symbol with three "Xs" indicates that the item has been surface decontaminated by locally approved procedures, bagged or contained in an agent-tight barrier, of sufficient volume to permit sample air to be withdrawn without being diluted with incoming air, and that appropriate tests or monitoring have verified that concentrations of 0.0001 mg/m^3 for agent GB, 0.00001 mg/m^3 for agent VX, 0.003 mg/m^3 for H or L, or (Unmasked worker AEL values for other covered chemicals) do not exist. Monitoring is not required for completely decontaminated and disassembled parts that are shaped simply (no crevices, threads, or the like) and are made of essentially impervious materials (such as simple lab glassware, and steel gears).

(3) An agent symbol with five "Xs" indicates an item has been decontaminated completely of the indicated agent and may be released for general use or sold to the general public. An item is decontaminated completely when the item has been subjected to procedures that are known to completely degrade the agent molecule, or when analyses, approved by the DDESB, have shown that the total quantity of agent is less than the minimal health effects dosage as determined by the Office of the Surgeon General of the Army.

c. Rooms containing or suspected of having been contaminated with agents shall be marked (near each entrance) at all times to indicate the level of contamination to be expected by entering personnel. This requirement does not apply to magazines.

(1) **5R - no agent hazard**. An agent symbol with five "Rs" means that all previously contaminated surfaces are decontaminated and analyzed to demonstrate the absence of residual

agents. A room sealed (ventilation turned off) for at least 4 hours at a temperature of at least 70 degrees Fahrenheit prior to sampling which shows an agent vapor concentration less than the 8 hour TWA concentration for unmasked workers is considered "5R".

(2) **4R - controlled agent vapor hazard.** An agent symbol with four "Rs" means that all previously contaminated surfaces are decontaminated by locally approved procedures, and air sampling indicates agent concentrations less than the 8-hour TWA(s) for unmasked workers. The air is sampled (at a temperature of 70 degrees Fahrenheit or greater) with the normal ventilation system operating.

(3) **3R - contained agent hazard.** An agent symbol with three "Rs" indicates that any agents are in configurations which, if left undisturbed, should prevent agent vapor or contact hazards.

(4) **2R - agent vapor hazard.** An agent symbol with two "Rs" indicates that any agents are in configurations which, if left undisturbed, prevent contact hazards.

(5) **lR - agent hazard.** An agent symbol with one "R" indicates the possibility of agent contact or vapor hazards, or agents in singly contained configurations which may leak. This includes rooms being used for operations which may cause agents to be released from engineering controls due to unforseen accidental causes such as in routine laboratory operations in fume hoods.

5. **Emergencies**

a. In case of accidental release of an agent that may result in personnel exposure, all nonessential and unprotected personnel shall evacuate immediately. Contaminated areas must be decontaminated, as appropriate, to applicable Table 11-1 AELs before normal operations are resumed.

b. Special medical surveillance shall be started within 24 hours for all personnel present in the potentially affected area at the time of the emergency.

c. The DoD Component shall maintain up-to-date Chemical Accident and Incident Control plans and conduct practice exercises of these plans at least annually.

6. **Chemical agent decontamination**

a. When chemical agents are spilled, or released, immediate action will be taken to contain the spill and clean up the agent in the immediate area of the spill.

b. Before leaving contaminated work areas, the external surfaces of the outer garments, and the protective boots and gloves shall be decontaminated.

c. When protective clothing becomes contaminated with chemical agents, the outside layer of clothing shall be removed and decontaminated as soon as possible.

d. Protective clothing and equipment that has been worn in known contaminated areas (agent detected) shall be decontaminated and monitored before reuse. Protective clothing and equipment contaminated with liquid mustard will not be reused. Protective clothing and equipment that has been worn in potentially contaminated areas (when no agent leakage has been visually observed or detected by use of field detection equipment) will be monitored before being moved to areas accessible to nonagent personnel.

e. Monitoring of protective clothing and equipment shall include containerization at 70 degrees Fahrenheit or higher for at least 4 hours, with subsequent analysis of a portion of the interior atmosphere of the container for the agent. The volume of the container, as well as the sample volume must be noted. See paragraph F.4.b., above. Plastic bags may be used as the container, if they have been tested and found to be effective for the purpose.

f. Since mustard penetrates into many protective materials with time, reuse of any protective clothing that has been contaminated with liquid mustard is not permitted.

g. Protective clothing that, after routine decontamination, is found to emit agent concentrations above the 3X level shall be destroyed.

h. Before chemical disposal systems are converted to different agents, piping, tanks, and so forth, of chemical disposal systems will be filled with decontaminating solution and a contact time of 10 half lives or greater will be provided. Walls and floors of process areas will be decontaminated to ensure the absence of contact hazards.

7. **Recertification of protective clothing**. After decontamination, clothing that has been determined to be 3X may be laundered, visually examined, and recertified by the DoD Component for use. Other items of toxicological agent protective clothing, such as boots and gloves, shall be tested, laundered, and recertified for use in the same manner.

8. **Transportation of materials contaminated with chemical agents**. Materials contaminated with chemical agents may be transported from one location to another. The material shall be encapsulated within an agent tight barrier. The following must be placed in compatibly lined drums or provided with other suitably tested containment before being transported: items potentially contaminated with liquid toxic chemical agent, items failing a XXX determination, or items suspected of offering hazards of percutaneous exposure to a chemical agent.

9. **Transportation of bulk agents and chemical ammunition**. The requirements established by AR 740-32, OPNAVINST 8070.1B, AFR 136-4 and MCO 4030.25B (reference (x)) shall be satisfied.

G. Engineering design guidance for facilities

1. **Air ventilation systems**. Air ventilation systems shall be designed and periodically tested to ensure that control of agent-contaminated exhaust will not exceed source emission limit of Table 11-1. Other design features that afford the same degree of safety may be used.

a. Filters or scrubbers for exhausted air shall be designed and approved for the MCE of the operations involved.

b. When high concentrations of agent are involved and breakthrough of agent can be expected, use of redundant filters shall be employed. Filters will be changed when agent breaks through the filter which is just upstream of the last filter as indicated by a gas life indicator, or calculations show that the first filter has absorbed one half of its design capacity.

c. All exhaust equipment will have backup blowers that engage automatically if the main blower fails.

d. Filter systems will be fitted with the means to measure the pressure drop across the filters.

e. Exhaust hoods and glove boxes will be designed to contain agents so that concentrations specified in Table 11-1 for unprotected personnel are not exceeded outside engineering controls. The design of these items will permit airflow adjustments sufficient to maintain the required protection level when laboratory equipment is in place.

(1) Catch basins and traps or spill trays of suitable size shall be provided within hoods and glove boxes.

(2) Glove boxes shall be used when the hazards analysis indicates that agent aerosols or dusts may be present during an operation.

f. Special design features shall be used when exposed explosives are involved to segregate explosives from air ventilation systems.

2. **Mechanical and utilities design for facilities**

a. The design parameters shall consider equipment and process layout, makeup airflow, and operational positions with regard to maintaining flow balance and cross currents. The system shall maintain negative pressure in operating areas in relation to hallways, offices, and other nonagent areas.

b. Working surfaces, such as walls, floors, and ceilings within a facility likely to be agent-contaminated during regular or accidental situations shall be constructed of agent resistant materials. Flooring shall cover wall surfaces to a height of 6 inches.

c. Utilities, mechanical rooms, and other nonagent areas shall be located so that air flows toward agent operating areas. Access to these non-agent areas shall be accomplished without entry into agent areas.

d. The electrical system shall be equipped with a backup power source designed to start automatically and supply enough power to support critical functions in the event of power outage. Wiring, controls, lightning protection, and other electrical devices shall meet the same requirements as defined in Chapter 6 and Chapter 7.

e. Safety showers and eyewash fountains shall be readily accessible to all personnel working with hazardous materials and shall be tested periodically.

f. All water outlets in the agent operational facility shall be fitted with effective devices to prevent backflow of water into the service lines.

g. Dedicated liquid waste systems shall be designed to collect and maintain any potentially agent-contaminated effluent produced by the activity until disposal in accordance with applicable laws. Vents or other openings in the waste system shall be fitted with approved agent filters.

h. Decontamination facilities of sufficient capacity to catch and contain liquid effluents shall be provided for agent operations. Adequate decontamination solution shall be available for immediate use on personnel or on facilities.

I. When operations require work assignments to be conducted at exposure levels above or potentially above the AEL for unprotected workers, change facilities with showers shall be provided.

3. **General design considerations**

a. **Facility alarms and monitors for engineering systems**. Each chemical facility shall have a master alarm and control panel that will permit functional verification of the exhaust blowers and airhandlers. Visual and audible alert alarms will be keyed to this master alarm panel to indicate failures.

b. **Fire detection and protection**. Fire detection and protection systems for production and maintenance facilities shall comply with the requirements and guidelines published in ARLCD-CR-80049 (reference (y)).

c. **Bulk storage tanks**. Impermeable dikes of enough capacity to hold at least 110 percent of the tank capacity plus the required volume of decontaminant solution shall be placed around all bulk agent tanks, reactors, and mixers. A system designed to pump the agent from the dikes to a vessel designed to accommodate the decontamination will satisfy the requirement that the dike contain sufficient volume for the decontaminating solutions.

d. **Isolation of facility functions**. The agent facilities will be designed to isolate unrelated activities by physical barriers or approved engineering controls. Design criteria shall prevent explosives from entering drain lines and sumps containing agents.

e. **Monitoring**. Air monitoring stations shall be established around chemical operational areas and storage areas to determine if Table 11-1 AELs are exceeded. In laboratory environments this requirement is met by routine area monitors and stack sampling.

(1) Monitoring analyses conducted for the purpose of demonstrating compliance with AELs will be based on certified reference materials.

(2) Monitoring analyses conducted for the purpose demonstrating compliance with AELs will be conducted under quality assurance plans that address the following issues:

(a) Production, characterization, and storage of certified reference materials.

(b) Documentation of precision, accuracy and quantification limits of analytical methodology.

(c) External oversight of laboratory results.

f. **Agent operational areas**. The chemical handling and maintenance areas associated with industrial operations shall be isolated from the main facility and shall be operated at a negative pressure with respect to the main facility area. The agent handling rooms shall be equipped with local exhaust ventilation which may be cascaded to more contaminated areas and exhausted out of a common exhaust stack. All air leaving the facility shall be filtered through redundant filter banks or other DDESB approved methods of decontaminating contaminated exhaust. The flow of air (negative pressures) shall go from less hazardous to more hazardous as based upon agent concentrations.

H. Classification of military-peculiar chemical materials and ammunition

1. **Chemical materials**. For purposes of storing and handling, chemical materials have been divided into groups as listed in Chapter 3, section D., as subdivided below, based on the action of the agent, the degree and type of hazard and the type of protection required.

a. **Chemical Group A**. Group A shall include highly toxic liquid agents, which in either liquid or vapor form, may be absorbed through the respiratory tract, the skin, or the eyes (for example, nerve agent, mustard). Exposure to Chemical Group A agents may cause serious damage to body functions or death, depending on the degree of exposure involved. Protection from these agents requires that full coverage, protective clothing and protective mask be worn.

b. **Chemical Group B**. Group B (for example, Phosgene, CN, CN-DM, BZ, CS, NC, etc.) shall include chemical materials (gaseous, liquids or solids) which are toxic or incapacitating by inhalation, ingestion or percutaneous absorption. Wearing of suitable respiratory protection is required for the protection of personnel against inhalation of vapors, particles or smoke from burning agents. Exposure to these materials may be fatal. Since these agents will cause varying degrees of skin irritation, approved types of protective clothing (such as coveralls, respiratory protection, gloves, and so forth) shall be provided and worn. This group consists of choking agents, blood agents, riot control agents, and screening smokes.

c. **Chemical Group C**. This group shall include materials which are spontaneously combustible (WP and PWP) and for which special fire fighting techniques and materials are required. Personnel protection will be of the type that will provide protection against fire and heat. Protection from inhalation of smoke from burning materials is required.

d. **Chemical Group D**. This group consists of signaling smokes and incendiary (for example, TH, IM, NP, PTI) material for which conventional fire fighting methods except use of water may be used. Protection from inhalation of smoke from burning incendiary mixtures is required.

2. **Chemical ammunition**. The same group designations used for chemical materials shall be used for chemical ammunition. The chemical and storage compatibility groups are the same for the chemical material and the ammunition item containing the material.

CHAPTER 12

REAL PROPERTY CONTAMINATED WITH AMMUNITION, EXPLOSIVES OR CHEMICAL AGENTS

A. Scope

This chapter contains particular policies and procedures necessary to provide protection to personnel as a result of DoD ammunition, explosives, or chemical agents contamination of real property currently and formerly owned, leased or used by the Department of Defense. This includes manufacturing areas, including pads, pits, basins, ponds, streams, burial sites; and other locations incident to such operations. The identification and control measures are in addition to, not substitutes for, those generally applicable to DoD real-property management. Contamination as used in this chapter refers in all cases to contamination with ammunition, explosives, or chemical agents.

B. Policy

1. All means practicable shall be used to protect members of the general public from exposure to hazards from contaminated real property currently or formerly under DoD ownership or control.

2. Permanent contamination of real property by final disposal of ammunition and explosives or chemical agents is prohibited. This prohibition extends to disposal by land burial; by discharge onto watersheds or into sewers, streams, lakes, or waterways. This policy does not preclude burial to control fragments during authorized destruction by detonation when these procedures are authorized by the DoD Component concerned and compliance with applicable statutes and regulations relative to environmental safeguards is ensured.

3. Real property that is known to be contaminated with ammunition, explosives, or chemical agents must be decontaminated using the most appropriate technology to the extent necessary to ensure protection of the public consistent with the proposed end use of the property.

C. Procedures

1. Identification and control (active installations)

a. Permanent records shall be created and maintained for each installation, ammunition plant, depot, laboratory, range, and ammunition holding areas to identify clearly all contaminated areas. These records shall indicate known and suspect areas, positively identify contamination by nomenclature, hazard, quantity, exact locations, and dud rates. All decontamination efforts shall be similarly detailed. If the installation is deactivated, the decontamination records shall be transferred to the office designated by the DoD Component concerned to ensure permanent retention.

b. All contaminated locations shall be placarded appropriately with permanent signs that prohibit entrance of unauthorized personnel. The DoD Component concerned shall ensure periodically that such signs are restored and maintained in a legible condition.

c. Active firing ranges, demolition grounds, and explosives test areas shall be assumed to be contaminated with unexploded ordnance (UXO) explosive material and shall be controlled accordingly. Access to these areas shall be controlled by the DoD Component.

2. **Land disposal (active installations)**

a. The plans for leasing, transferring, excessing, disposing, and/or remediating DoD real property when ammunition, explosives, or chemical agents contamination exists or is suspected to exist, shall be submitted to DDESB for review and approval of the explosives safety aspects of the plan.

b. DoD Component land disposal submissions shall identify the intended end use of the property, the nature and extent of on- and off-post contamination, location of the contaminated land, any improvements that may have been made, proposed detection and degree of decontamination, and the extent to which the property may be used safely without further decontamination.

c. When accountability and control of real property contaminated with ammunition and explosives are transferred between DoD Components, the action shall be accompanied by the permanent record of contamination.

d. Ammunition, explosives, or chemical agents shall be removed until an acceptable level of protection is reached. Identification of degree and extent of contamination, an assessment of the potential for migration of contamination, and implementation of steps to halt such migration are necessary to accomplish proper cleanup. In addition, ammunition and explosives contamination shall be removed to appropriate depths in limited areas where the user activity warrants it. Transfer records shall detail past ammunition and explosive contamination and decontamination efforts; provide requisite residual contamination information; and advise the user not to excavate or drill in residual contamination areas without a metal detection survey. This information shall be enclosed along with the report of excess. This information will also be entered in the permanent land records of the civil jurisdiction in which the property is located.

e. Limited use land transfers may be arranged with other federal agencies for compatible use of contaminated real property, such as wildlife refuges, safety zones for federal power facilities, or other purposes not requiring entry except for personnel authorized by the DoD Component concerned. These land transfers shall include all restrictions and prohibitions concerning use of the real property to ensure appropriate protection of both operating personnel and the general public.

3. **Remediation of formerly used defense sites (FUDS)**

a. The DoD Component responsible for the remediation of the FUDS shall develop procedures to safely remediate those sites contaminated with ammunition, explosives, or chemical agents. These procedures will be provided to DDESB for review and approval. Priority will be given to the remediation of sites with contamination that poses an immediate public risk. Identification of the degree and extent of contamination, assessment of potential for migration of contamination, and implementation of steps to halt such migration will complement efforts to clean up FUDS.

b. Plans for the remediation of FUDS must be submitted to the DDESB for coordination (with regard to explosives and chemical agent safety). These plans should present the type of contaminations that are suspected to exist at the site; the techniques that will be used for the identification of the contamination; a risk assessment; and the measures that will be taken to minimize the risk to workers and the public during the contamination assessment, cleanup; and disposal phases. The DDESB will be notified if significant hazards arise during any of the above phases and require actions beyond the DDESB-approved FUDS procedures or actions beyond the specific FUDS remediation plan initially submitted for coordination to the DDESB.

4. **Remediation methods and use restrictions**

a. **Remediation planning**. The depth to which UXO remediation is necessary depends on the projected end-use of the land and the extent of potential human exposure.

(1) Information concerning the remediation and notification that additional cleanup is necessary before further and/or different use permitted will be included in applicable land disposal documents.

(2) The intended end use may be defined in law or by the end user which can be any combination of federal, state, local and private entities.

(3) The land's projected end use must be changed in those cases where UXO detection systems are not sensitive enough or funds are not available to remove UXO to the remediation depth.

(4) Documents about the remediation depth to which UXO was removed and the process by which that depth was determined must be included in the land disposal documents.

b. **Remediation process**. Remediation involves removing UXO from the specific parcel of land being transferred. This process includes several steps:

(1) Determine the land end-use. The end-use may be defined in federal law, stipulated by agreement or determined pursuant to a process established by state law and applied nondiscriminatory. Within a parcel of land, there may be multiple uses, such as wildlife refuge, livestock grazing, public highways and picnic area.

(2) Determine the boundaries of the area(s) to be investigated and remediated.

(3) Determine known or suspected UXO by type.

(4) Define the locations of UXO and the remediation depth(s).

(5) Remove or neutralize UXO. Where removal or neutralization of UXO to the defined remediation depth is not technologically feasible the remediation may not be adequate to permit the projected end use.

(6) Document the process.

(7) Make provisions for continued DoD surveillance of areas where UXO is above the frost line yet located below the remediation depth. (The Corps of Engineers is responsible for actions involving land returned to the public domain.) Such UXO could eventually migrate to the surface, requiring additional remediation.

c. **Site-specific remediation depth determination**. The preferred method to determine the remediation depths is to use site-specific information. The following information is needed for a site-specific determination:

(1) Characterize the site, including the boundaries, types of ordnance, and soil characteristics. This is done through searching historical documents, interview, and on-site investigation, as appropriate.

(2) Provide the estimated depth at which UXO may be present based on available records, technical data, and/or on-site investigation, as appropriate. This may be accomplished using a MAXIMUM ORDNANCE PENETRATION source document, such as the NOMOGRAPH found in Figure 4-8, TM 5-855-1 (reference (z)).

(3) Determine the risk associated with the end-use of the site assuming differing depths of remediation, in light of the ordnance types likely to be present and the said documentation.

(4) Using UXO depth estimate(s), establish remediation depths for the site-specific conditions.

d. The approved remediation plan may be modified based on actual conditions encountered during the remediation. For example, should UXO be consistently found at less than the predicted depths, the remediation depth may be reduced. The modification(s) will be documented, forwarded to DDESB for approval, and included in the land disposal documents.

e. **Assessment depth**. When site specific planning described in paragraph C.4.c., above, is not possible, the assessment depths provided below are used for interim planning.

Planned End Use	Depth
Unrestricted Commercial/Residential/ Utility/Subsurface Recreational Construction Activity	10 Ft *
Public Access Farming/Agriculture/Surface Recreation/Vehicle Parking/Surface Supply Storage	4 Ft
Limited Public Access Livestock Grazing/Wildlife Preserve	1 Ft
Not Yet Determined	Surface
Like Use (Remediation will be consistent with Service regulations concerning routine maintenance of impact areas).	

* (Assessment planning at construction sites for any projected end use requires looking at the possibility of UXO presence 4 ft below planned excavation depths).

f. Land disposal documents must include notice that there would be increased risks to operations and public safety if violations of the end use were to occur.

D. Mineral exploration and extraction

1. Ammunition and explosives facilities.

a. Mineral exploration and drilling activities are to be separated from ammunition and explosives operating and storage facilities by public traffic route explosives safety distances provided there is to be no occupancy of the site by personnel when the exploration or drilling is completed, and by inhabited building explosives safety distances if occupancy is to continue when exploration or drilling is completed. If chemical agents or munitions are present, public exclusion distances must be maintained to the exploration or drilling activities. Examples of exploration activities are seismic or other geophysical tests. Examples of drilling activities are those for exploration or extraction of oil, gas, and geothermal energy.

b. Mining activities are to be separated from ammunition and explosives operating and storage facilities by inhabited building explosives safety distances. If chemical agents or munitions are present, public exclusion distances must be maintained to the mining activities. Examples of mining activities are strip, shaft, open pit, and placer mining, which normally require the presence of operating personnel.

2. **Contaminated lands**. Exploration, drilling, and mining are prohibited on the surface of explosives or chemical agent contaminated lands. Exploration and extraction is permitted by directional (slant) drilling at a depth greater than 50 feet beneath the explosives contaminated land surface or by shaft mining at a depth greater than 100 feet beneath such land surface.

3. **Safety review of exploration and extraction plans**. Military Department approved plans for mineral exploration and extraction on land that is in proximity to ammunition and explosives facilities or land that is contaminated or suspected to be contaminated with explosives shall be forwarded to the DDESB for safety review and approval. Submission will include information necessary for explosives safety evaluation consistent with subsection C.2., above. Relationships with other PES should be included.

CHAPTER 13

MISHAP REPORTING AND INVESTIGATION REQUIREMENTS

A. Scope

1. The ammunition, explosives, and chemical agent mishaps that shall be reported and investigated in accordance with this Chapter are specified by enclosure 5 to DoD Instruction 6055.7 (reference (aa)). Mishap reports submitted to DDESB shall be prepared in accordance with implementing regulations to reference (aa). This reporting requirement has been assigned Report Control Symbol DD-A&T(AR)1020 in accordance with DoD 8910.1-M (reference (a)).

2. This Chapter sets forth the minimum data to be included in all mishap reports submitted to the DDESB.

3. Serious mishaps reported to the DDESB under this requirement need not be reported separately to the Director for Safety and Occupational Health, Office of the Deputy Under Secretary of Defense (Environmental Security) (ODUSD(E)) under the special reporting requirements of enclosure 3 to DoD Instruction 6055.7 (reference (aa)).

B. Report classification

Mishap reports should be unclassified whenever possible to ease appropriate dissemination of useful safety information to DoD Components, industry, and allied governments.

C. Initial reports

1. Telephonic and electrically transmitted reports shall be provided as soon as possible and shall include as much of the following data as may be immediately available.

a. Name and location of the reporting activity.

b. Name, title, and telephone number of person reporting, and of contact at the scene of the accident.

c. Location of mishap (activity, city, installation, building number or designation, road names, or similar information).

d. Item nomenclature (Mk, Mod, FSC, NIN, DODAC, or NALC).

e. Quantity involved (number of items and NEW).

f. Day, date, and local time of initial significant event and when discovered.

g. Description of significant events (include type of operation involved).

h. Number of fatalities (military, DoD civilian, or other civilian).

i. Number of persons injured (military, DoD civilian, or other civilian).

j. Description of material damage (government or nongovernment).

k. Material damage cost (government or nongovernment).

l. Cause.

m. Action taken or planned (corrective, investigative, or EOD assistance).

n. Effect on production, operation, mission, or other activity.

o. Details of any remaining chemical agent hazard or contamination, if applicable.

p. Are any news media aware (yes or no).

2. Regardless of format, mishap reports prepared or received in compliance with other DoD Component regulatory documents may be used to satisfy these reporting requirements whenever they contain similar data.

D. Followup reports

1. Followup reports shall be submitted to the DDESB by way of priority-precedence, electrically-transmitted message within 2 workdays after notification of an occurrence has been received and shall contain any additional detailed information on the data elements contained in section C., above.

2. Regardless of format, supplemental mishap reports prepared or received in compliance with other DoD Component regulatory documents also may be used to satisfy the followup reporting requirement whenever they contain similar data.

E. Investigation reports

1. **Event circumstances**. The following data, as applicable, shall be included as a part of the mishap investigation reports. Chemical agent mishaps shall also require the inclusion of the data specified in section F., below.

a. Location, date, and local time.

b. Type of operation or transportation mode engaged in at time of the mishap (include reference to applicable standing operating procedure or regulatory document).

c. Description of mishap.

d. Quantity, type, lot number, configuration, and packaging of ammunition, explosives, or chemical agents involved in mishap.

e. Type of reaction or reactions.

(1) Single reaction, such as detonation, deflagration, fire, release, or activation.

(2) Multiple reaction, such as detonation and fire.

(3) Communication of reactions, such as fire caused fire, fire caused detonation, and detonation caused detonation, and the time between events.

f. Possible or known causes.

2. **Event effects**. A copy of aerial and ground photographs taken of the mishap site shall be submitted to the DDESB as soon as possible after the occurence. When appropriate, include

photographs (color, whenever possible), maps, charts, and overlays, showing or listing the following data.

a. Number of persons killed or injured (military, DoD civilian, or other civilian). Indicate cause of fatalities and injuries, and location of affected persons with respect to the mishap origin.

b. Property damage at the mishap origin (government or nongovernment).

c. Area containing property with complete destruction (more than 75 percent).

d. Area containing property damage beyond economical repair (50 to 75 percent).

e. Area containing repairable property damage (1 to 49 percent). Indicate event origin, and a description of the damage and its cause.

f. Radii of uniform and of irregular glass breakage. When possible, include type and dimensions of glass broken at farthest point.

g. Locations and dimensions of craters.

h. Distances from the mishap origin at which direct propagation occurred, and whether from blast, fragments, or firebrands.

i. Approximate number, size, and location of hazardous fragments and debris.

3. **Factors contributing to or limiting event effects**. When appropriate, describe the influence of the following factors on the mishap:

a. Environmental and meteorological, such as cloud cover, wind direction and velocity, temperature, relative humidity, electromagnetic radiation (EMR), and electrostatic buildup and/or discharge.

b. Topography, such as hills, forests, and lakes.

c. Structural features at the mishap origin, such as exterior and interior walls and bulkheads, roofs and overheads, doors and hatches, cells or magazines, earth cover, and barricades.

d. Safety features, other than structural, at the mishap origin, such as remote controls, sprinkler or deluge systems, detectors, alarms, blast traps, and suppressive shielding.

e. **Structures**. Position, orientation, and type of construction of all structures, damaged or not, located within maximum radius of damage. When either the applicable intermagazine, intraline, or inhabited building distances are greater than the radius of actual damage, show the location, orientation, and type construction of all structures situated within the Q-D radii.

f. **Vessels, vehicles, and mobile equipment**. Location within maximum radius of damage, or if the Q-D requirements are greater, location within the K9, K18, K24, and K30 Q-D radii.

g. **Personnel**. Location within maximum radius of damage, or if the Q-D requirements are greater, location within the K9, K18, K40, and K50 Q-D radii.

h. **Explosives, ammunition, and chemical agents**. Location, type, configuration, amounts, and protection provided within maximum radius of damage, or if the Q-D requirements are greater, location within the applicable magazine and intraline radii.

4. Analyses, conclusions, and recommendations.

F. Chemical agent mishaps

In addition to the data required by section E., above, for ammunition and explosives mishaps, each chemical agent mishap investigation report shall contain the following information.

1. **Injuries**

a. The safety training that personnel received applicable to duty being performed at the time of the mishap.

b. The availability, type, and use of protective equipment.

c. A description of the emergency measures taken or performed by individuals at the scene of the mishap.

d. A summary of applicable medical data.

e. A sketch showing locations where disabling injuries occurred, and indicating the distance and direction from the agent source.

2. **Mishap area**. In addition to the environmental and meteorological data required by paragraph E.3.a., above, indicate:

a. The facility filter types and the facility ventilation and air turnover rates.

b. The rate and manner of agent release and any other data used to determine the downwind hazard.

c. The status and disposition of chemical agent remaining at the mishap.

d. The details of any remaining chemical agent hazard and contamination, if applicable.

APPENDIX A

GLOSSARY

Explanation of terms. The following are descriptions of terms and phrases commonly used in conjunction with ammunition, explosives, and other dangerous materials. These are listed to provide a degree of uniformity of description in the use of technical information throughout these standards:

1. **Aboveground magazines**. Any type of magazine abovegrade other than standard or nonstandard earth-covered types of magazines.

2. **Action level**. One-half of the exposure limit for a chemical agent averaged over an 8-hour work shift.

3. **Administration area**. The area in which are located administrative buildings that function for the installation as a whole, excluding those offices located near and directly serving components of explosives storage and operating areas.

4. **Aircraft passenger transport operations**. Passenger transport operations for the purpose of applying explosives Q-D tables are defined as follows: Passenger transport traffic involving military dependents and civilians other than those employed by or working directly for DoD Components. The following are not considered passenger transport operations.

a. Infrequent flights of base and command administrative aircraft that may, on occasion, provide some space available travel to authorized personnel.

b. Travel of direct hire appropriated funds personnel employed by any DoD Component.

c. Travel of such personnel as contractor and technical representatives traveling to or from direct support assignments at DoD installations.

5. **Ammunition and explosives**. Includes (but is not necessarily limited to) all items of U.S.-titled (owned by the U.S. Government through DoD Components) ammunition; propellants, liquid and solid; pyrotechnics; high explosives; guided missiles; warheads; devices; devices, and chemical agent substances and components presenting real or potential hazards to life, property and the environment. Excluded are wholly inert items and nuclear warheads and devices, except for considerations of storage and stowage compatibility, blast, fire, and non-nuclear fragment hazards associated with the explosives.

6. **Ammunition and explosives aircraft cargo area**. Any area specifically designated for:

a. Aircraft loading or unloading of transportation configured ammunition and explosives.

b. Parking aircraft loaded with transportation configured ammunition and explosives.

7. **Ammunition and explosives area**. An area specifically designated and set aside from other portions of an installation for the development, manufacture, testing, maintenance, storage, or handling of ammunition and explosives.

8. **Anchorages**

a. **Scuttling site**. An area of water specifically designated for positioning a ship for its flooding or sinking under emergency situations.

b. **Explosives anchorage**. An area of water specifically designated for loading and unloading vessels and for anchoring vessels carrying a cargo of ammunition and explosives.

9. **Auxiliary building**. Any building accessory to or maintained and operated to serve an operating building, line, plant, or pier area. Explosive materials are not present in an auxiliary building, such as powerplants and change houses, paint and solvent lockers, and similar facilities.

10. **Barricade**. An intervening barrier, natural or artificial, of such type, size, and construction as to limit in a prescribed manner the effect of an explosion on nearby buildings or exposures.

11. **Blast impulse**. The product of the overpressure from the blast wave of an explosion and the time during which it acts at a given point (that is, the area under the positive phase of the overpressure-time curve).

12. **Blast overpressure**. The pressure, exceeding the ambient pressure, manifested in the shock wave of an explosion.

13. **Cavern storage site**. A natural cavern or former mining excavation adapted for the storage of ammunition and explosives.

14. **Ceiling value**. The concentration of chemical agent that may not be exceeded for any period of time.

15. **Chamber storage site**. An excavated chamber or series of excavated chambers especially suited to the storage of ammunition an explosives. A cavern may be subdivided or otherwise structurally modified for use as a chamber storage site.

16. **Chemical agent**. A substance that is intended for military use with lethal or incapacitating effects upon personnel through its chemical properties. Excluded from chemical agents for purposes of this Standard are riot control agents, chemical herbicides, smoke- and flame-producing items, and individual dissociated components of chemical agent ammunition.

17. **Classification yard**. A railroad yard used for receiving, dispatching, classifying, and switching of cars.

18. **Closure block**. A protective construction feature designed to seal the entrance tunnel to an underground storage chamber in the event of an explosion within the chamber. Magae blocks are passive closures that are driven by the blast from a normally open to a closed position. Klotz blocks are active closures, operated by a hydraulic system to move from a normally closed to an open position (for access).

19. **Combat aircraft parking area**. Any area specifically designated for:

a. Aircraft loading or unloading of combat-configured munitions.

b. Parking aircraft loaded with combat-configured munitions.

20. **Compatibility**. Ammunition or explosives are considered compatible if they may be stored or transported together without increasing significantly either the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident.

21. **Connected-chamber storage site**. A chamber storage site consisting of two or more chambers connected by ducts or passageways. Such chambers may be at the ends of branch tunnels off a main passageway.

22. **Controlling authority**. The headquarters of the DoD Component concerned.

23. **Debris**. Any solid particle thrown by an explosion or other strong energetic reaction. For aboveground detonations, debris usually refers to secondary fragments. For underground storage facilities, debris refers to both primary and secondary fragments, which are transported by a strong flow of detonation gasses.

24. **Debris trap**. A protective construction feature in an underground storage facility which is designed to capture fragments and debris from a detonation within the facility. This is usually accomplished by using the inertia of the material to separate it from the detonation gas stream. (Illustrated in Figure 9-3)

25. **Deflagration**. A rapid chemical reaction in which the output of heat is enough to enable the reaction to proceed and be accelerated without input of heat from another source. Deflagration is a surface phenomenon with the reaction products flowing away from the unreacted material along the surface at subsonic velocity. The effect of a true deflagration under confinement is an explosion. Confinement of the reaction increases pressure, rate of reaction and temperature, and may cause transition into a detonation.

26. **Detonation**. A violent chemical reaction within a chemical compound or mechanical mixture evolving heat and pressure. A detonation is a reaction which proceeds through the reacted material toward the unreacted material at a supersonic velocity. The result of the chemical reaction is exertion of extremely high pressure on the surrounding medium forming a propagating shock wave that originally is of supersonic velocity. A detonation, when the material is located on or near the surface of the ground, is characterized normally by a crater.

27. **Dividing wall**. A wall designed to prevent, control, or delay propagation of an explosion between quantities of explosives on opposite sides of the wall.

28. **DoD mishap**. An unplanned event or series of events that result in damage to DoD property, occupational illness to DoD military or civilian personnel, injury to DoD military personnel on or off duty, injury to on-duty civilian personnel; damage to public and private property, or injury and illness to non-DoD personnel as a result of DoD operations.

29. **Dolphin**. A mooring post or posts on a wharf or quay.

30. **Donor/acceptor**. A total quantity of stored ammunition may be subdivided into separate storage units in order to reduce the MCE, and, consequently, the Q-D of an accidental detonation. The separation distances, with or without an intervening barrier, should be sufficient to ensure that a detonation does not propagate from one unit to another. For convenience the storage unit which detonates is termed the donor, and nearby units, which may be endangered, are termed acceptors. The locations of the donor and acceptor define the PES and ES, respectively.

31. **Engineering controls**. Regulation of facility operations through the use of prudent engineering principles, such as facility design, operation sequencing, equipment selection, and process limitations.

32. **Expansion chamber**. A protective construction feature in an underground storage facility which is designed to reduce the blast shock and overpressure exiting the facility by increasing the total volume of the complex. It may also function as an operating area within the underground facility, as well as a debris trap. (Illustrated in Figure 9-3)

33. **Explosion**. A chemical reaction of any chemical compound or mechanical mixture that, when initiated, undergoes a very rapid combustion or decomposition releasing large volumes of highly heated gases that exert pressure on the surrounding medium. Also, a mechanical reaction in which failure of the container causes the sudden release of pressure from within a pressure vessel, for example, pressure rupture of a steam boiler. Depending on the rate of energy release, an explosion can be categorized as a deflagration, a detonation, or pressure rupture.

34. **Explosives facility**. Any structure or location containing ammunition and explosives excluding combat aircraft parking areas or ammunition and explosives aircraft cargo areas.

35. **Exposed site (ES)**. A location exposed to the potential hazardous effects (blast, fragments, debris, and heat flux) from an explosion at a potential explosion site (PES). The distance to a PES and the level of protection required for an ES determine the quantity of ammunition or explosives permitted in a PES.

36. **Firebrand**. A projected burning or hot fragment whose thermal energy is transferred to a receptor.

37. **Fragmentation**. The breaking up of the confining material of a chemical compound or mechanical mixture when an explosion takes place. Fragments may be complete items, subassemblies, pieces thereof, or pieces of equipment or buildings containing the items.

38. **Hazardous fragment**. A hazardous fragment is one having an impact energy of 58 ft-lb or greater.

39. **Hazardous fragment density**. A density of hazardous fragments exceeding one per 600 sq. ft.

40. **High explosive equivalent or explosive equivalent**. The amount of a standard explosive that, when detonated, will produce a blast effect comparable to that which results at the same distances from the detonation or explosion of a given amount of the material or which performance is being evaluated. It usually is expressed as a percentage of the total net weight of all reactive materials contained in the item or system. For the purpose of these standards, TNT is used for comparison.

41. **Holding yard**. A location for groups of railcars, trucks, or trailers used to hold ammunition, explosives, and dangerous materials for interim periods before storage or shipment.

42. **Hygroscopic**. A tendency of material to absorb moisture from its surroundings.

43. **Hypergolic**. A property of various combinations of chemical to self ignite upon contact with each other without a spark or other external initiation.

44. **Inhabited buildings**. Buildings or structures, other than operating buildings occupied in whole or in part by human beings, both within and outside DoD establishments. They include but are not limited to schools, churches, residences (quarters), Service clubs, aircraft passenger terminals, stores, shops, factories, hospitals, theaters, mess halls, post offices, and post exchanges.

45. **Inspection station**. A designated location at which trucks and railcars containing ammunition and explosives are inspected.

46. **Interchange yard**. An area set aside for the exchange of railroad cars or vehicles between the common carrier and DoD activities.

47. **Intraline distance**. The distance to be maintained between any two operating buildings and sites within an operating line, of which at least one contains or is designed to contain explosives, except that the distance from a service magazine for the line to the nearest operating building may be not less than the intraline distance required for the quantity of explosives contained in the service magazine.

48. **Joint DoD - non-DoD use runway/taxiway**. A runway and/or taxiway serving both DoD and commercial aircraft. A runway and/or taxiway serving solely DoD, chartered, or Non-DoD aircraft on DoD authorized business is not joint use.

49. **Launch pads**. The load-bearing base, apron, or platform upon which a rocket, missile, or space vehicle and its launcher rest during launching.

50. **Liquid propellants**. Substances in fluid form (including cryogenics) used for propulsion or operating power for missiles, rockets, ammunition and other related devices (See Table 9-17). For purposes of this standard, liquid fuels and oxidizers are considered propellants even when stored and handled separately.

51. **Loading density**. Quantity of explosive per unit volume. usually expressed as either pounds per cubic foot (lbs/ft^3). As applied to underground storage facilities, there are two types of loading densities used in Q-D calculations:

a. Chamber loading density is based on the NEW within an individual storage chamber and the volume of the chamber (V_{CH}).

b. The calculation of airblast peak pressures and IBD's for explosions in underground storage facilities is based on the shock-engulfed volume (V_E) of the facility. This is the total volume filled by the expanding gases at the time the blast front reaches the point of interest (e.g., the entrance to an adjacent chamber). It includes volumes in any direction that the gases can enter, to a distance from the explosion source that equals the distance from the source to the point of interest. For IBD, the point of interest is the tunnel opening.

52. **Loading docks**. Facilities, structures, or paved areas, designed and installed for transferring ammunition and explosives between any two modes of transportation.

53. **Lunchrooms**. Facilities where food is prepared or brought for distribution by food service personnel. It may serve more than one PES. A breakroom in an operating building may be used by personnel assigned to the PES to eat meals.

54. **Magazine**. Any building or structure, except an operating building, used for the storage of ammunition and explosives.

55. **Magazine, earth-covered, nonstandard**. All earth-covered magazines except those listed in subsection B.1., Chapter 5 with earth covering equal to or greater than that required by standard igloo magazines.

56. **Mass-detonating explosives**. HE, black powder, certain propellants, certain pyrotechnics, and other similar explosives, alone or in combination, or loaded into various types of ammunition or containers, most of the entire quantity of which can be expected to explode virtually instantaneously when a small portion is subjected to fire, to severe concussion or impact, to the impulse of an initiating agent, or to the effect of a considerable discharge of energy from without. Such an explosion normally will cause severe structural damage to adjacent objects. Explosion propagation may occur immediately to other items of ammunition and explosives stored sufficiently close to and not adequately protected from the initially exploding pile with a time interval short enough so that two or more quantities must be considered as one for Q-D purposes.

57. **Maximum credible event (MCE)**

a. **General**. In hazards evaluation, the MCE from a hypothesized accidental explosion, fire, or agent release is the worst single event that is likely to occur from a given quantity and disposition of ammunition and explosives. The event must be realistic with a reasonable probability of occurrence considering the explosion propagation, burning rate characteristics, and physical protection given to the items involved. The MCE evaluated on this basis may then be used as a basis for effects calculations and casualty predictions.

b. **Chemical agent**. An MCE for a chemical agent is defined as the hypothesized maximum quantity of agent that could be released from an ammunition item (without explosives), bulk container, or process as a result of a single unintended, unplanned, or accidental occurrence. It must be realistic with a reasonable probability of occurrence.

58. **Navigable streams**. Those parts of streams, channels, or canals capable of being used in their ordinary or maintained condition as highways of commerce over which trade and travel are or may be conducted in the customary modes, not including streams that are not capable of navigation by barges, tugboats, and other large vessels unless they are used extensively and regularly for the operation of pleasure boats.

59. **NEQ**. Net explosive quantity expressed in kilograms.

60. **NEW**. Net explosive weight expressed in pounds.

61. **Nitrogen padding (or blanket)**. Used to fill the void or ullage of a closed container with nitrogen gas to prevent oxidation of the chemical contained therein and to avoid formation of a flammable mixture, or to maintain a nitrogen atmosphere in or around an operation or piece of equipment.

62. **Non-DoD Components**. Any entity (government, private, or corporate) that is not a part of the Department of Defense.

63. **Operating building**. Any structure, except a magazine, in which operations pertaining to manufacturing, processing, handling, loading, or assembling of ammunition and explosives are performed.

64. **Operating line**. A group of buildings, facilities, or related work stations so arranged as to permit performance of the consecutive steps in the manufacture of an explosive, or in the loading, assembly, modification, and maintenance of ammunition.

65. **Operational shield**. A barrier constructed at a particular location or around a particular machine or operating station to protect personnel, material, or equipment from the effects of a possible localized fire or explosion.

66. **Passenger railroad**. Any steam, diesel, electric, or other railroad which carries passengers for hire.

67. **PEL**. The maximum time-weighted average airborne concentration (milligrams per cubic meter) of a chemical agent to which it is believed that essentially all members of a specific population can be exposed for a specific period without adverse effect.

68. **PES**. The location of a quantity of explosives that will create a blast, fragment, thermal, or debris hazard in the event of an accidental explosion of its contents. Quantity limits for ammunition and explosives at a PES are determined by the distance to an ES.

69. **Pier**. A landing place or platform built into the water, perpendicular or oblique to the shore, for the berthing of vessels.

70. **Prohibited area**. A specifically designated area at airfields, seadromes, or heliports in which all ammunition and explosives facilities are prohibited.

71. **Public access exclusion distance**. The distance arc (calculated) from the agent source at which no more than 10.0, 4.3, and 150 milligrams per minute per cubic meter is present for GB, VX, and mustard, respectively.

72. **Public traffic route**. Any public street, road, highway, navigable stream, or passenger railroad (includes roads on a military reservation that are used routinely by the general public for through traffic).

73. **Q-D**. The quantity of explosive material and distance separation relationships that provide defined types of protection. These relationships are based on levels of risk considered acceptable for the stipulated exposures and are tabulated in the appropriate Q-D tables. Separation distances are not absolute safe distances but are relative protective or safe distances. Greater distances than those shown in the tables shall be used whenever practicable.

74. **Quay**. A marginal wharf or solid fill.

75. **Robust munitions**. These are munitions having a ratio of the explosive weight to empty case weight less than 1.00 and a nominal wall thickness of at least 0.4 inches. Examples of robust ammunition includes MK 80 series bombs, M107 projectiles, Tomahawk and Harpoon penetration warheads and 20, 25, and 30 mm cartridges. Examples of non-robust ammunition include CBUs, torpedo warheads, underwater mines, and TOW, Hellfire, Sparrow and Sidewinder missiles. Unless otherwise noted, all air-to-air missile warheads are defined as non-robust.

76. **Rock strength**. Strong, moderately strong, and weak rock are designators which provide a general classification of rock types for siting underground storage facilities for ground shock hazards. Classification of a rock body into one of these three rankings is based on the rock impedance factor:

rock impedance factor = $\rho \cdot c \cdot 10^{-6}$

and $\rho = \gamma/g$

where

γ is the rock density, lbs/ft^3

g is the gravitational acceleration, ft/sec^2

ρ is the mass density of the rock, lbs-sec^2/ft^4

c seismic velocity of the rock, ft/sec.

The rock impedance factor will be 0.75 or more for strong rock; between 0.75 and 0.5 for moderately strong rock; and less than 0.5 for weak rock.

Values of these parameters can usually be estimated based on examinations of exposed rock outcrops or core samples from an exploratory drill hole. For the detailed design of an underground storage facility (maximum span width, rock reinforcement, etc.), standard rock mechanics classification systems should be used.

77. **Runway**. Any surface on land designated for aircraft takeoff and landing operations, or a designated lane of water for takeoff and landing operations of seaplanes.

78. **Service magazine**. A building of an operating line used for the intermediate storage of explosives materials.

79. **Ship or barge units**. All explosives within a line encompassing the ship or barge being loaded, the space on the pier for spotting of freight cars and trucks, and the space in the water for barges which may be working the ship or barge.

80. **Single-chamber storage site**. An excavated chamber with its own access to the natural ground surface, not connected to any other storage chamber.

81. **Source emission limits**. The amount of chemical agent that may be released at a particular point that allows for natural dilution, ventilation, and meteorological conditions interfacing.

82. **Spall**. Spall refers to pieces of a material (and the process by which they are formed) that are broken loose from the surface of a parent body by tensile forces that are created when a compression shock wave travels through the body and reflects from the surface. For underground storage, spall normally refers to the rock broken loose from the wall of an acceptor chamber by the shock wave transmitted through the rock from an explosion in a nearby donor chamber.

83. **Standard igloo magazine**. An earth-covered, arch-type magazine, with or without a separate door barricade, constructed according to an approved standard drawing identified in subsection B.1. of Chapter 5.

84. **Static test stand**. Locations on which liquid propellant engines or solid propellant motors are tested in place.

85. **Support facilities**. Ammunition and explosives storage or operations that support solely the functions of tactical or using units as distinguished from storage depots or manufacturing facilities.

86. **Suspect truck and car site**. A designated location for placing trucks and railcars containing ammunition or explosives that are suspected of being in a hazardous condition. These sites are also used for trucks and railcars that may be in a condition that is hazardous to their contents.

87. **Tactical facilities**. Tactical facilities are prepared locations with an assigned combat mission, such as missile launch facilities, alert aircraft parking areas, or fixed gun positions.

88. **Taxiway or taxilane**. Any surface designated as such in the basic airfield clearance criteria specified by a DoD Component publication or Federal Aviation Regulation (reference (p)).

89. **Toxic area**. A defined area in which CG K ammunition or Class 6 chemical agents are handled or stored.

90. **Ufer Ground**. A Ufer Ground is an earth electrode system which consists of solid conductors encased along the bottom of a concrete foundation footing or floor in direct contact with earth.

91. **Unexploded Ordnance.** Explosive ordnance which has been primed, fuzed, armed or otherwise prepared for action, and which has been fired, dropped, launched, projected or placed in such a manner as to constitute a hazard to operations, installations, personnel or material an remains unexploded either by malfunction or design or for any other cause.

92. **Unit risk**. The risk to personnel and/or facilities that is associated with debris, fragment and/or blast hazards that is the result of the detonation of a single round of ammunition.

93. **Wharf**. A landing place or platform built into the water or along the shore for the berthing of vessels.

94. **Wharf yard**. A yard that is close to piers or wharves in which railcars or trucks are held for short periods of time before delivery to the piers or wharves.